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ELECTRIC CONTROLS AND GOVERNORS FOR ASTRONOMICAL INSTRUMENTS.*

F. L. O. WADSWORTH.

In the January number of ASTRONOMY AND ASTRO-PHYSICS, in an interesting article on Telescope Mountings and Domes, Professor Pickering suggests the use of reversible electric motors for actuating each of the slow motion screws of the telescope. This plan has been used over a year in the control of the large siderostat of the Astro-Physical Observatory, and it has proved so thoroughly convenient and satisfactory, that a brief description of the mechanical and electrical features may be of interest.

The instrument in question has already been described in some detail by the maker.†

Briefly it is of the Foucault type similar to the one used by Professor Langley at Allegheny, but of much larger size, being intended to carry a mirror 20 inches in diameter. In order to overcome as far as possible the difficulties inherent in this form of instrument, all of the driving parts were made very heavy and stiff and the clock-work is unusually powerful.

The governor is of the usual Grubb type and was originally supplemented by a very ingenious but elaborate electrical device for controlling the rate of rotation of the driving shaft, by a free seconds pendulum, through the medium of two mouse controls, one arranged to slowly accelerate, the other to slowly retard the motion of the shaft in question. In addition to this, another mouse control, on the same shaft was arranged to be operated, by the observer, to further accelerate or retard the motion, of the clock at will. Slow motions were also provided for the motion in declination and in altitude and azimuth, all of these slow motions (eight in all) being actuated mechanically by means of cords or long rods running from the instrument to the observer who was inside the Observatory and nearly fifty feet from the instrument.

This system of mechanical controls had always been unsatisfactory because of the number of cords and rods involved and the

* Communicated by the author.
† See article by Grubb in Engineering, Vol. XLIX, p. 592.

limitations imposed by their use on the position of the observer while making these adjustments.

Various plans had been, from time to time, proposed by Professor Langley, Dr. Hallock and others connected with the Observatory, for replacing them with a form of electric control which, by pressing a key on a small moveable switch-board, would enable any one of the slow motion mechanisms to be operated in either direction from an electric motor. The advantages of this method of control are obvious but the mechanism necessary to carry out the proposed plans was so complex, and the expense and liability to get out of order so great, that they had never been practically adopted. When, however, the idea of using a single motor was abandoned and the plan referred to at the beginning of this article, *i. e.*, that of driving each slow motion independently by means of a small reversible motor, which in the case of the altitude and declination slow motions could be placed directly on the moving parts to which the screws for these motions were attached, was proposed by the author, the mechanical difficulties at once disappeared and the electrical features were considerably simplified.

The motors required were all so small that the additional expense involved by the use of four instead of one was inconsiderable, and more than compensated for, in the simplification in the mechanical work alone. It was found also that this plan involved the use of a smaller number of wires than any before proposed, the whole eight motions, *viz.*, forward and backward in right ascension, declination, altitude and azimuth requiring but five wires running from the switch-board by the observer to the instrument.*

The general arrangement of the electrical connections is that shown in Figure 1, where *s* is the switch-board (here considerably enlarged in relation to the other parts for the sake of clearness, but in reality so small and compact, that it may readily be carried in the observer's hand if desired), provided with four reversing keys, each of which controls one of the four double motions.

They are so arranged that the motions of the contact lever handle in either direction from the center, sends the reflected beams from the siderostat in the same direction, so that they may be manipulated readily in the dark without confusion or error. Any ordinary form of reversing key may be used of

† The electric control supplied by the maker required 10 wires for the control in right ascension alone.

course, but the one shown is particularly simple and easy of construction.

It consists simply, of two brass springs, *a*, *b*, screwed to an insulating handle pivoted midway between them, and four brass contact buttons, 1, 2, 3, 4, diagonally opposite buttons being attached to the two battery and motor terminals.

The motors could be reversed either by reversing the polarity of the fields, or by reversing the current in the armature, but for certain practical reasons the latter plan is preferable. The polarity of the field could be most easily kept constant, as the motors are all very small, by using permanent steel magnets, but for reasons of economy commercial motors with electro magnetic fields were used, and their field coils connected in series with an independent battery circuit, which was closed automatically by a relay R in the main circuit,—which dispenses with the necessity of running two additional wires to the switch-board.

In the first, of the two plates, which accompanies this article, the two motors which operate the mouse controls in right ascension and declination are shown. As will be seen they are directly connected by belts to two mouse controls, one on the driving shaft of the clock; the other on a shaft which moves the declination axis.* Those which control the altitude and azimuth slow motion have not yet been put in place, as these adjustments are only used for special work.

The electric control, supplied by the maker, a portion of which is shown at the right of the lower motor, has now been entirely discarded, as too complicated and liable to derangement.

Its place is fully supplied by the use of the motor, whose speed of rotation and therefore of regulation, can be adjusted to a nicety by means of the rheostat M, in the motor circuit.

This makes it possible to either keep the image fixed on the cross wires or to give it any desired rate of motion forward or backward or up and down in the field without altering the rate of the clock, an advantage of considerable importance in certain kinds of spectroscopic work.

Other advantages are the smoothness and regularity of the motion, which can be instantly checked, even when very rapid, by a momentary reversal of the motor, and the ease with which the motion can be controlled from parts of the laboratory to which it would be difficult if not impossible to carry the mechanical controls either because of the distance or on account of intervening apparatus.

* I agree with Professor Pickering in considering the mouse control decidedly superior to the usual worm and worm-wheel, or slow motion screw.

The only trouble which was at first experienced was the effect of the motor circuits on the delicate galvanometer used in the Observatory, but this has been overcome, by careful twisting of the wires together and the relocation of the batteries and rheostat.

The use of a motor in place of the usual clock as the driving power for not only equatorials, but also for siderostats, chronographs, and in fact all instruments where uniformity of rotation is desired, is something which the writer has long advocated and adopted whenever possible.

In these days when storage batteries form an almost necessary part of the equipment of every laboratory, mechanical driving clocks could be replaced with advantage in almost every instance by suitably designed electric motors; but on account of the unfamiliarity of most of our leading instrument-makers with the correct principles of design, and the unsuitability of most of the commercial motors in the market, it will probably be a long time before we can hope to see this change made.

The points which have to be considered in the general design of an electric motor which it is desired to have run with the greatest possible regularity and constancy are:

1. The motor should be much larger than is actually required to do the work, so that the load upon it may be at all times very light, and its counter electro-motive force therefore very nearly equal to the difference of potential between the terminals.

2. The motor should be compound wound with a powerful field worked considerably below the saturation point to secure a sensitive regulation, both for changes of load and slight variations on *E M F* at the terminals.

3. The armature should be of the drum type, with wires either buried in slots and covered with a wrapping of fine iron binding wire, or better, passed through holes near the outer circumference of the armature as in the Wenstrom dynamo type. It should of course be very perfectly balanced, and if not of considerable weight itself should have a heavy flywheel. The commutator should be of large size, with many segments, and together with the brushes should be kept scrupulously clean and free from oil and dust.

4. The electromotive force should be as high as possible both to minimize the effects due to changes in the individual cells of the battery and to eliminate as far as possible the effects due to momentary bad contact of the brushes, etc.

If these conditions are fulfilled and a good storage battery is

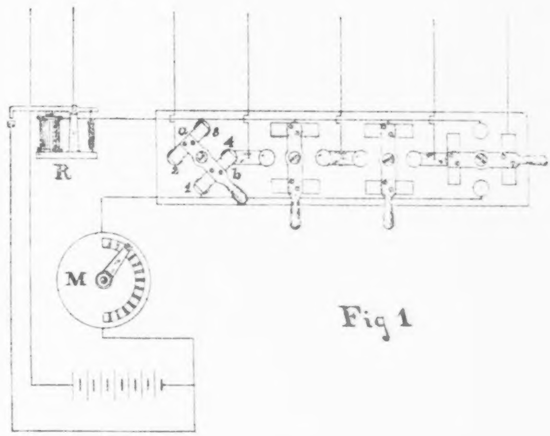


Fig 1

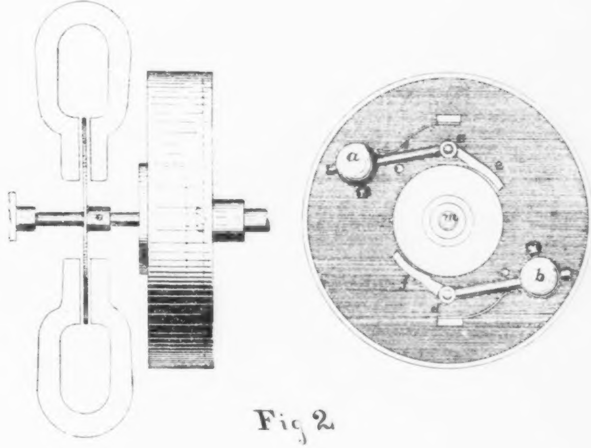


Fig 2

used to furnish the current, there is no need for a special regulator unless the most extreme accuracy of rotation is desired.

Then the method of governing from an electric fork, which was first suggested and applied by Lord Rayleigh,* furnishes an almost ideal means of securing and maintaining any desired speed. The form of motor used by Lord Rayleigh, however, is only one of many that may be used for the purpose. When working with the revolving mirror in 1891, I considered many plans for driving it in perfect synchronism with a tuning fork by an alternating electric motor, whose circuit was interrupted by the tuning fork, using another motor such as the ordinary air turbine, or a special continuous current motor of the type just described, to furnish the main part of the power. Any form of synchronous motor can be used for the alternating or governing motor but those in which both armature and field coils are stationary are preferable for this speed work.†

It will be noted that the number of revolutions of the motor may be made any sub-multiple of the number of vibrations of the fork by simply increasing the number of poles and armature coils and any desired speed thus obtained without the use of gearing.

There are however other methods of mechanically regulating the speed of electric motors, almost as sensitive as that by the use of the tuning fork.

Any form of clock or chronograph governor can be used to regulate the speed, not by the clumsy method of absorbing an excess of power by the introduction of intermittent frictional resistance, but by more rationally supplying power in proportion to the work done, either by cutting in, or throwing out sections of the field coil, as the speed rises or falls, or even better, by moving a third brush over the commutator (three brush method of regulation).

As regards the mechanical construction of the governor itself, the field has been so thoroughly exploited that there would seem little more to be done. Nevertheless I will venture to describe a form of governor which I have recently designed, and which possesses, I think, one very important advantage in that the action resulting from a change of speed is instantaneous, whereas all forms of governors which govern by centrifugal force alone, require a certain small time to act. Figure 2 is an end view showing the general principle of action. The two governor balls *a*, *b*,

* Philosophical Transactions, Vol. 174, p. 317.

† Such a form together with other special forms of dynamos and motors, was described by the author in *Electrical World*, Vol. XVI, p. 183, "Some New Forms of Dynamos."

PLATE VIII.

APPARATUS FOR ELECTRICAL CONTROL AT EYE-END OF TELESCOPE.

are carried on levers pivoted on pins *c*, *d*, which are behind the balls as regards the direction of rotation, and in such a position that the arc of motion is inclined at a considerable angle to the radial line drawn through any part of the path.

The centrifugal force is counteracted by any form of spring in which the extension of the spring and therefore its restraining force is proportioned to the distance *mb ma* of the ball from the axes of rotation, under which conditions the governor will be strictly isochronous, *i. e.*, the centrifugal force and the restraining force of the spring will be in exact equilibrium for any position of the balls at some definite speed which will be determined by the relation between the weight of the balls and the strength of the spring. This form of governor, which in engineering practice is designated as a shaft governor, is now used almost to the exclusion of the old gravity forms, similar to those still used on chronographs, because of the readiness with which this isochronism can be obtained, for any definite speed and the more powerful governing action secured. The particular point to which it is desired to call attention, however, is the arrangement of pivots with relation to the balls and the direction of revolution, by means of which the inertia of the balls themselves comes into play on the instant of a change of speed and causes them to assume the position to which the centrifugal force alone would bring them only after the change of speed had become well established.

This principal of governing by inertia does not seem to be generally understood and it is surprising that a large proportion of the engine governors now in use are exactly wrong: *viz.*, the ball is placed behind the pivot, instead of in front, thereby causing the centrifugal and inertial forces to at first oppose one another, and still farther delaying the regulation of the speed.

The motion of the balls and levers may be used in any desired way to effect the desired regulation, for instance, if regulation by frictional resistance is required a very simple way is to provide the levers with break shoes *e*, *f*, which will be thrown inward against the dotted drum, which revolves with some degree of friction on a bearing concentric with the axis of the governor wheel. But a better arrangement than any depending on mechanical friction is secured by attaching to *n** a copper disc or drum *n* placed between the poles of two or more powerful magnets. When the drum *n* and the attached disc revolve, strong Foucault currents are set up in the latter, and exert a retarding force on the motion which is nearly proportioned to the speed.

* The *n* was omitted in the copy of Fig. 2.

When used in conjunction with the electric motor these governors would be mounted directly on the shaft and arranged to vary the current in the field or armature (best in the former) in the way previously suggested.

ASTRO-PHYSICAL LABORATORY, Washington, D. C.
Smithsonian Institution, January, 1894.

ON THE FORMS OF THE DISCS OF THE SATELLITES OF JUPITER AS SEEN WITH THE 36-INCH EQUATORIAL OF THE LICK OBSERVATORY.*

E. E. BARNARD.

In ASTRONOMY AND ASTRO-PHYSICS for March, May and June 1893, Professor W. H. Pickering has given a series of very interesting papers on the forms of the satellites of Jupiter as seen at Arequipa.

As the observations contained therein are of a remarkable nature and one of such vital importance to our knowledge of the physical condition of the satellite system of Jupiter, they should be verified before being finally accepted. But coming as they do from a station where the atmospheric conditions are said to be very perfect, they should be treated with respectful consideration pending their complete verification.

I have naturally been very much interested in the subject, and though my previous observations of these moons lead me to accept these statements with caution, yet in consideration of the favorable location of the Observatory at Arequipa, it was deemed best to make a careful re-examination of the forms of the satellites under the best atmospheric conditions with our great telescope, before deciding in my own mind as to the reality of the Arequipa results.

Since my return to the Lick Observatory, during the past fall and winter, I have taken occasion when the opportunity afforded to examine the forms of the discs of the four bright moons of Jupiter.

These satellites—at least three of them, I, III and IV—often undergo singular transformations of apparent form during certain stages of their transits across the face of Jupiter. These anomalies, as is well known, are in the main due to surface markings on the satellites. Though I had often seen these pecularities yet I had never seen any of these moons other than round when off the disk of the planet.

* Communicated by the author.

In dealing with the Arequipa observations, let us assume that the atmospheric conditions at that station are perfect, as has been claimed. This gives a wonderful advantage in examining the surface markings of a planet or satellite.

But the main question in this case, or at least the one to which I shall devote my criticism, is the forms of the discs of the satellites. It seems to me that the ease with which any malformation could be detected is mainly a function of the aperture of the telescope—assuming only that the definition is good enough to permit the use of proper magnifying power. Therefore the 36-inch refractor of the Lick Observatory is unquestionably better adapted to settle a question of this kind than a 13-inch—even though the 13-inch may have a better atmosphere to work in, and I am not sure that it has.

It would be absurd to claim that the separating power of a 13-inch is equal to that of a 36-inch—both being good glasses by the same maker, and working under nearly equal atmospheric conditions—yet it seems to me this is essentially what the Arequipa observations must claim, for the 36-inch does not verify them.

No one knows better than I that there are certain circumstances where a five or six-inch telescope may show an object that cannot be seen with a 36-inch—such for instance as diffuse nebulous and cometary matter. As a matter of fact there are objects in the heavens that the naked eye shows better than any telescope—such as the zodiacal light and gegenschein. The subject in question, however, is not that of diffused and hazy light, but compact and clearly defined bodies with clear cut discs, where the bigger and more powerful the telescope the better they must be seen.

Understanding this, it must be clear that the Lick telescope should be a criterion in this case and by its verdict, if rightly interpreted by me, the Arequipa observations of the forms of these satellites must stand or fall.

Let it be understood, however, that my observations and criticisms have no reference to the observations of the surface markings or the theories of the physical conditions of the satellites, as contained in the papers under criticism.

From my observations with the 36-inch I have collected the following notes on the forms of these satellites when seen off the disc of Jupiter. A power of 1000 diameters has been uniformly used, as recommended by Professor Pickering, several times however when the conditions permitted, a still higher power was used.

To show the conditions of seeing or steadiness of the image I have assumed five as representing the best definition. For convenience of future reference the Standard Pacific Time (8 hours slow of Greenwich) is given.

From a desire to explain the anomalous appearance of the Ist. satellite when in transit Sept. 8, 1890 (see M. N. for February, 1894), I had previously examined this satellite with the 36-inch with Mr. Burnham several times in hope of getting some explanation of its apparent duplicity at the transit mentioned. 1891, Oct. 8, Mr. Burnham and I carefully examined the form of the first satellite near elongation. Seeing 4 to 5; power 350 to 1500. Jupiter on the meridian.

The satellite was perfectly round. Mr. Burnham examined it carefully and was positive that it was perfectly round. We also examined II, III and IV, and they were perfectly round.

There was a white spot at the south limb of III, observation from $9^h\ 11^m$ to $9^h\ 40^m$. Later we examined I again, seeing 3 to 4, from $10^h\ 36^m$ to $10^h\ 56^m$. During glimpses of good seeing the satellite was perfectly round to us both.

1891, Oct. 16. From $9^h\ 35^m$ to $9^h\ 50^m$ we again examined the first satellite. Seeing from 2 to 3. During moments of best definition I was perfectly round, as also was II in field with it.

Everyone familiar with Mr. Burnham's extraordinary keenness of vision, and his wonderful power of detecting any defect in the roundness of the image of a star, will agree at once that this satellite must have been round on these occasions.

Since then I have examined the satellites with the 36-inch, the observations bearing directly upon the verification of those made at Arequipa. Some of these observations I quote here, with 1,000 diameters unless otherwise stated.

1893, August 27.	$16^h\ 10^m$ to $16^h\ 37^m$.		Seeing = 4. All four of the satellites perfectly round.
August 28.	14^h	30^m	All four are round.
Sept. 3.	13	0	All four are round.
	14	45	Satellite I is perfectly round. Seeing = 4.
	17	0	Seeing = 4, each of the satellites is round.
Sept. 17.	17	25	Seeing = 5. All four are round.
Sept. 24.	12	48	III is perfectly round.
	13	15	All four are round.
	17	32	III perfectly round.
Sept. 25.	14	50	I is perfectly round.
	15	0	All four are round and clearly defined.
Oct. 1.	13	30	III with 1,500 perfectly round.
	14	50	I, II, III perfectly round.
	16	40	I and III perfectly round, seeing = 4.

Oct.	1.	17^h	30^m	Seeing = 4. I, II, III are round.
	29.	12	30	Seeing = 5. All the satellites are round.
Nov.	6.	11	54	III is beautifully round.
		14	40	III is perfectly round. Seeing = 4.
Nov.	12.	10	15	III is perfectly round.
Dec.	3.			I is near transit, following, it appears slightly elongated towards Jupiter.
Dec.	10.	9	25	All four are round. Seeing = 3. North Pole of III is white.
		12	5	All are round. The south Pole of IV is light. The N. Pole of III is light. Seeing = 4.
Dec.	11.	9	18	I, II, III each is round. IV seems a little deficient on following side as if a slight phase existed. Bright spot at south Pole of IV. Bright spot at north Pole of III.
1894. Jan.	28.	6^h 50^m to 6^h 55^m,		I, II, III are round. IV is slightly deficient on following side as if a slight phase or a dark area existed on it.

In *Monthly Notices* of the R. A. S. for February, 1894, I have given an account of the discovery of a bright belt on satellite I. It seems to me that with a very high magnifying power and not the best seeing, the duskiness of the poles of this satellite and its white equatorial belt might give the appearance of elongation towards the planet as noted by me Dec. 3. But Professor Pickering would not be deceived by this.

From the drawings given in ASTRONOMY AND ASTRO-PHYSICS for June, 1893, the distortions of the satellite discs are so conspicuous, that it would seem impossible for them to escape detection with our great telescope, even with the most casual observation, and for such to elude a careful and conscientious inspection would be very remarkable indeed.

It seems to me that with a very high magnifying power on a small telescope, the surface markings of the satellites themselves, when near the edges of their discs, might readily cause an apparent distortion of the satellites, as these same markings certainly do when the satellite is seen in transit.

APPEARANCES OF THE IIIRD SATELLITE IN TRANSIT.

In reference to the observations of the IIIrd satellite on September 17-24 and Nov. 6, 1893, perhaps a few more details may be of interest.

On September 17th, a dusky belt on this satellite was quite a noticeable feature. It was possible to determine the position angle of this with considerable precision. 13^h 40^m (St. P. T.) from four settings, the position angle was 108°.3. Mr. Garrett P.

Serviss of Brooklyn, New York, who was in the dome with me at the time, also saw the belt clearly. One setting of the wires by this gentlemen gave the position angle 114°. We both agreed that there was a diffusion of this belt towards the south near the following limb of the satellite. The last contact of III with Jupiter at emergence from transit was at $13^h\ 53^m$ St. P. T.

Sept. 24. The satellite was very much deformed during transit; the south preceding part of the disc being deficient, giving it the appearance shown in the sketch. There was evidently a dark spot on the *s. p.* portion of the satellite, this being about the same shade as that portion of Jupiter, caused the south preceding portion of III to be undistinguishable from the surface of the planet. A fragment of a dusky belt was also seen cutting across the lower visible portion of the satellite. After emerging from the face of Jupiter, III was perfectly round, and the dusky belt could be seen as on Sept. 17. At mid-transit the south limb of III was tangent with the south limb of Jupiter.

Following are observations of III when entering transit:

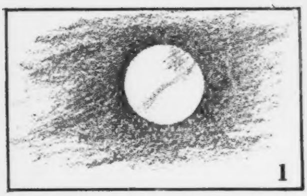
First contact satellite and planet	16^h	$4^m.5$	St. P. T.
Satellite ½ on	16	19 .5	" "
Satellite completely inside the disc	16	30 .0	" "

Nov. 6. The belt and dusky spot were seen again. At $11^h\ 45^m$ two settings of the wires gave 111°.3 as the position angle of the belt. The phenomena of the transit of Sept. 24, was repeated except that the defective part was smaller—the satellite presenting a slightly different face to us. The transit was observed with 1000 diameters and the seeing = 4. The two drawings of this date are self explanatory. The one before the satellite entered in transit, shows a dusky region on its north preceding side, and this being of the same depth of shade as the planet on which it was later projected, gave the appearance of a defect in the symmetry of the satellite when in transit, as shown in the second drawing.

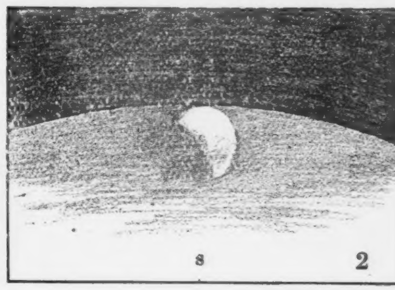
Comparing the first of these two drawings with that of September 17 it will be seen that, if the dusky shading is the same in both cases, and I think it is, the satellite period of rotation is different from that of its revolution about Jupiter. From this marking, if it is permanent, the rotation of the satellite can be easily determined, and I hope, if circumstances permit, to decide this question at the next opposition of Jupiter.

In these cases the satellite off the disc was perfectly round, but while on the face of the planet was defective, and this was obviously caused by the dusky marking.

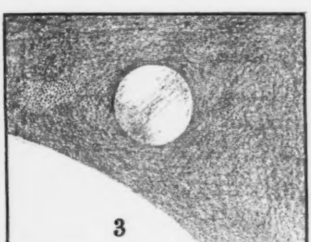
PLATE VIII *a*.



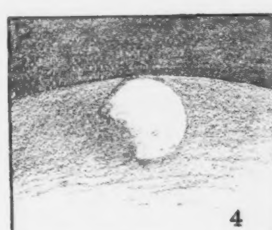
1893, Sept. 17, 14^h 10^m.



1893, Sept. 24, 16^h 58^m.
In Transit.



1893, Nov. 6, 11^h 54^m.
Before Transit.



1893, Nov. 6, 13^h 35^m.
In Transit.

Phenomena of Jupiter's IIId Satellite.
36-inch Equatorial.

Transparency of the Limb of Jupiter.

Among the many questionable phenomena of Jupiter and his moons there is one that seems to have gained a respectable footing in astronomical literature. It has been more than once claimed that the satellites have been seen through the limb of Jupiter when undergoing occultation.

In my mind this has been due to either poor seeing, a poor telescope or "an excited observer."

For nearly fifteen years I have observed Jupiter and his satellites, and with telescopes all the way from 5 inches up to 36 inches have tried to see this phenomenon. I have often watched the satellites under first class seeing with the 12-inch here at occultation, but have never seen one of them through the limb of Jupiter though that phenomenon was specially looked for.

I have also made the following notes on this subject with the 36-inch.

1891, Oct. 22d, Mr. Burnham and I watched satellite II at occultation. Seeing = 4. The limb of Jupiter seen distinctly cutting the satellite. When last seen there was only the tiniest speck of II protruding—this quickly disappeared. Neither of us, taking turns, could see the slightest trace of the satellite through the planet. It passed behind a part of the limb where one of the dark belts should join it.

1892, Aug. 12. $16^h\ 6^m\ 48^s$ Standard Pacific Time. Satellite II bisected in coming out from occultation. Carefully watched for any trace of it through Jupiter. It was sharply cut by the limb of the planet which was sharply defined. The satellite was strongly contrasted with the limb but no trace of it could be seen through the planet. Seeing = 5. First class observation.

1892, Sept. 14. $14^h\ 17^m\ 17^s$ Standard Pacific Time. Satellite I bisected at emergence from occultation. Sharply cut by the limb, no trace of it through the planet. Seeing = 5.

1893, Sept. 3. $14^h\ 39^m\ 23^s$ St. P. Time. Satellite I bisected coming out from occultation. Beautifully cut by the limb. No trace of it through Jupiter. It came out at the end of a heavy narrow belt north. Satellite very white compared with the limb —a strong contrast.

These observations have been made with care, with the most powerful telescope that to-day can be applied to such observations, and the limb of Jupiter has appeared perfectly opaque—as at all previous observations with the smaller telescopes.

I think it is high time that astronomers reject the idea that the

satellites of Jupiter can be seen through his limb at occultation. When the seeing is bad there is a spurious limb to Jupiter that well might give the appearance of transparency at the the occultation of a satellite. But under first class conditions the limb of Jupiter is perfectly opaque. It is quibbling and begging the question altogether to say that the phenomenon of transparency may be a rare one and so have escaped my observation. Has any one said yet that the Moon was transparent when a star has been seen projected on it when it ought to have been behind?

MT. HAMILTON, 1894, March 8.

MECHANICAL CAUSES OF THE FORMATION, MOTION AND PERIODICITY OF THE SUN SPOTS.*

J. M. SCHAEBERLE.

In previous papers bearing more directly upon the form of the Sun's corona, I have repeatedly stated that the observed data obtained during solar eclipses indicated that the corona was the visible representation of ejective effects produced by forces acting mainly in the Sun's spot zones. No attempt was made to assign the reason why the solar forces should be most active in particular regions; the observed fact was simply made use of to explain certain other phenomena.

The object of the present paper is to point out that according to mechanical principles every incandescant rotating liquid or gaseous body undergoes periodical surface changes in the form of zonal waves of varying surface strength accompanied by changes of internal pressure.

Any non-rotating incandescent liquid or gaseous mass in space will, through the action of gravity and heat radiation, tend to assume a spherical form, the temperature at the surface being lower than the interior. For any given element the increase of temperature and pressure with the depth below the surface places each particle in a state of unstable equilibrium, so that any disturbance of this condition at once results in a series of ascending heated currents and descending cooled currents of matter, such that at any given instant the density, temperature and radial velocity at the surface of any given spherical shell within the body will be the same at every point of the shell. If now a motion of rotation is given to the sphere, the homogeneity of the surface of any given shell is completely destroyed.

* Communicated by the author.

The actual conditions relating to variation in temperature, velocity, density, etc., are unknown, as is also the form of the complete equations for determining the relative motions of the rotating mass. The general effect of these internal forces can, however, be traced with considerable certainty, as will be shown in this paper.

As the direct cause of the non-homogeneity of any spherical shell is the angular motion, we shall only consider those relative motions which are due to axial rotation.

In the following table relative values are given for the rudely approximate conditions existing for particles enclosed between the two bounding surfaces of any thin spherical shell and the two conical bounding surfaces of an intersecting spherical sector having a small constant breadth in latitude, the axis of the sector coinciding with the axis of rotation.

Latitude.	Mass.	Relative Velocity.		Relative Momentum.	
		Radial.	Tangential.	Radial.	Tangential.
0°	350	1000	0	350	0
10	344	970	171	334	59
20	328	884	321	290	105
30	302	750	433	226	131
40	268	587	493	157	132
50	224	413	493	93	110
60	174	250	433	43	75
70	119	117	321	14	38
80	61	30	171	2	10
90	2	0	0	0	0

The last column of the above table shows that at the beginning of rotation the tendency of the surface matter to move toward the equator is greatest in the middle latitudes, the kinetic energy of the mass moving towards the equator is also greatest in the same latitudes.

For the sake of brevity four figures have been drawn which give a graphical representation of what would require too much space to describe in full.

In Fig. (1) the length of a normal ordinate to the boundaries of the shaded areas Q, Q, represents the relative magnitude of mass-motion towards the equator, *at the beginning of rotation*, for any given latitude. The curved full lines drawn tangent to the dotted radial lines indicate, in a general way, the paths of particles in different latitudes, moving from the interior towards

the surface. The rate of curvature of these paths increases with an increase in the velocity of rotation.

Now submerged particles in a zone of given latitude, come to the surface in a zone of less latitude, consequently the resulting angular surface velocity will in general be less than the equatorial taken as a standard as has already been pointed out by Faye. The retardation from this cause will be greatest in the middle latitudes.

In Fig. (1) for instance, a series of submerged particles on radii cutting the surface at the points K′, R′, T′ all on the same meridian, come to the surface at the points K, R, T all in less latitudes, with linear velocities corresponding to greater latitudes a consequent retardation of angular velocity results from this change in latitude.

The retardation from this curve is zero at the equator and at the poles and a maximum in middle latitudes.

The ordinates to the black radial area are roughly proportional to the amount of retardation per unit of time for different latitudes.

Where the surface flow is greatest the density *at the beginning of rotation* will be least, as the heated matter from the interior is allowed easiest access to the surface, consequently the thickness or density of the cooled surface will be at a maximum at each pole and at the equator, while the minimum density will be in the middle latitudes. The normal ordinates from the circumference to the curve H, H, roughly represent the variation of density of the surface due to longer exposure to the cold of space.

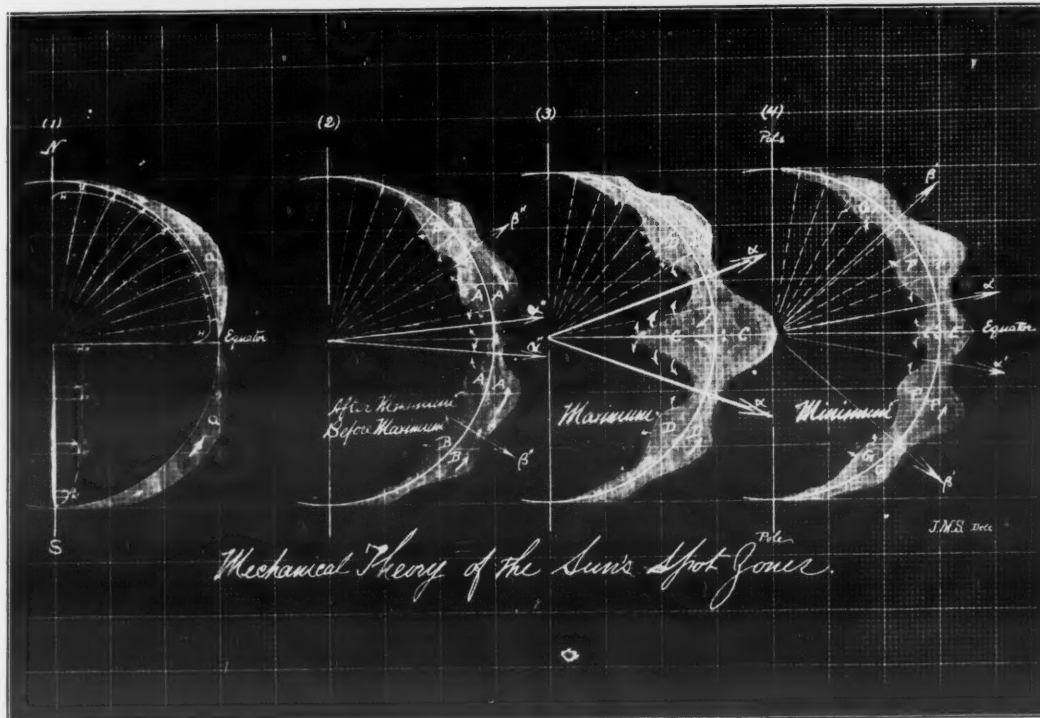
The above described conditions refer to the forces in operation immediately after an originally non-rotating incandescent liquid or gaseous body has been forced to have a motion of rotation about a central axis.

The ordinates to the shaded wave-like areas in Fig. (2) roughly represent the relative surface strength which must exist in the now spheroidal mass at some subsequent instant of time. As the surface flow towards the equator is greater in the middle latitudes than it is in lower latitudes, cooled matter must evidently, for a time, pile up as at AA, and also at the equator where the flow is from opposite directions.

Fig. (3) represents a still later phase in which the masses previously at AA have reached the equator forming the great mass *c*, while those of BB have moved on to DD.

Fig. (4) represents the conditions in which the waves have mean values. The changing surface conditions illustrated in

PLATE IX.


(1)
N
Equator
S
(2)
After Minimum
Before Maximum
(3)
Maximum
(4)
Pole
Minimum
Equator
Pole
J.M.S. Delt
Mechanical Theory of the Sun's Spot Zones.

Figs. (2), (3), (4), (2), etc., will follow each other periodically, in the order given, so long as the rotating body retains its liquid or gaseous state.

The following laws based on purely mechanical principles are probably true throughout the whole universe.

Every incandescent rotating liquid or gaseous body in space which has assumed the spheroidal form undergoes periodical changes both of its surface and of internal pressure. The zones of greatest and least surface strength are parallel to and continually move towards the equator of the rotating body. The surface density, in the polar regions is always comparatively great.

In all such bodies the angular velocity of the surface will be greatest at the equator.

Applying this new principle of zonal-wave motions to the theory of our Sun a very simple explanation of the hitherto puzzling phenomena of the periodicity and motions of solar disturbances is obtained.

Without reference to the actual condition of matter at the Sun's surface (whether liquid or gaseous) it is safe to say that the temperature is lower than the interior, and that the greater the amount of moving surface matter in a given zone the greater will be the depression of this matter below the general surface of the spheroid, and the greater will be the amount of energy developed by the expansion of that portion of the cooled matter of which is forced to flow inward. The forces developed will always be such that there is a constant tendency to drive adjacent matter away from the crest of a zonal wave; so that the general flow towards the equator will, for a time, be retarded in latitudes greater than that of the zonal crest, and accelerated for lower latitudes.

In Figs. (2), (3) and (4) the long radial lines or arrows $\alpha, \alpha', \alpha''$, β, β', β'' drawn through the depressions in the shaded areas, indicate the positions of the zones of least surface strength. In Fig. (2) the zones α'', α'' moving towards the equator are about to be reinforced by the advancing masses A, A. The expression of inflowing matter due to the excess of pressure at A A, retards the velocity of adjacent matter in higher latitudes, causing secondary crests as at BB, and intermediate zones of weakness β'', β''. These systems of strong and weak surface zones follow each other and have a general motion towards the equator. The internal pressure will evidently reach a maximum when the masses A, A, from both hemispheres unite at the equator, as in Fig. (3), where they are forced to flow inwards; the expansion of this inflowing cooled matter causes an increase of internal pres-

sure which will be greatest in a submerged equatorial zone. The zones of weakness α'', α'', no longer exist while β'', β'', have now moved on to the positions α, α. After the greater portion of the cooler mass C has been forced into the interior the excess of pressure due to its expansion becomes less, and the standard masses D, D, are again accelerated. New zones of strength and weakness form and travel towards the equator in endless succession in the order represented by the surface waves of Figs. (3), (4), (2), (3), etc. If for any reason two crests or two depressions do not reach the equator at the same time differences of phase will result in the two hemispheres.

For a perfectly symmetrical distribution of the forces and motions it might also happen that after long intervals of time such final conditions of things might result that the zones of strength and weakness (crests and depressions) would for periods remain fixed in latitude. Unbalanced forces due to a lack of perfect homogeneity of the mass would, however, constantly tend to recreate zonal waves moving towards the equator.

The interval of time between two successive similar phases in a given zone will depend upon the fluidity of the mass and the velocity of rotation. For a mean surface velocity of three miles per hour (towards the equator) the periodic time will be about eleven years in the case of a body as large as the Sun.

Starting from a mean condition of the solar surface as represented by Fig. (4), the principle zones of weakness are at α', α', β', β', and eruptions on the surface will be mostly confined to these zones. Owing to the mass motion the eruptions at α'', α'', will gradually disappear as the zone approaches the equator at the same time those in the zone β'', β'', will increase in number both on account of the stoppage of the rents in the zone α'', α'', and because of the diminishing distance of the zones β'', β'', from submerged equatorial region of greatest pressure. This pressure will evidently reach a maximum for the conditions represented in Fig. (3), in which the submerged equatorial zone of cooler matter attains its greatest volume. The neighboring zones of weakness α, α, Fig. (3) most readily give way to the excess of pressure, and evidently the direction of the streams of ejected matter which form the corona may at times deviate very largely from the normal; the magnitude of this deviation depending upon the relative positions of the center of greatest force and the surface of least strength at which an eruption takes place. Gaps or rifts in the corona will, in general, be found opposite the zones of greatest strength.

As to the causes which produce the phenomena observed in and around solar spots the limits of this paper prevent any extended remarks. The spectroscopic observations of Hale, Lockyer, Secchi, Young and others seem to demonstrate that the spots are caused by cooled matter coming from higher regions, and that the faculæ are probably the more highly heated masses rising from a lower level. The views of Secchi, that the spots are caused by streams of ejected matter falling back to the Sun near but not at the place of ejection, seem to offer the simplest explanation of the observed phenomena. Every spot once formed would represent a surface of great strength, thus offering greater resistance to eruptions from the interior than the more heated neighboring areas; and the indraft over such a spot would continually draw in cooled material from neighboring eruptions thus tending to perpetuate the spot long after the primary eruption has ceased to exist.

In agreement with the theory that the surface density at the poles of an incandescent rotating body is greater than at lower latitudes, observations show that in very high latitudes the eruptions are not only rare but when seen are found to be of comparatively short duration, so that conspicuous circumpolar spots would not be expected.

The application of the principle of zonal wave motions to the mechanics of our own atmosphere and also to that of Jupiter and its bearing upon the variability in the light of the fixed stars is reserved for a future paper.

LICK OBSERVATORY, March 7, 1894.

ADDRESS DELIVERED BY THE PRESIDENT, CAPTAIN W. DE W. ABNEY, C.B., R.E., D.C.L., F.R.S., ON PRESENTING THE GOLD MEDAL TO MR. S. W. BURNHAM.

The Gold Medal of the Royal Astronomical Society has been awarded by the Council to Mr. S. W. Burnham for his discovery and measurement of double stars; and following the custom of the Society, it is the duty of the President to lay before it the grounds on which the award has been made.

I can scarcely hope to do justice to the labors entailed in the extensive researches made by Mr. Burnham, and to his discoveries. I believe I am correct in stating that Mr. Burnham's first

astronomical communication was made to the *English Mechanic*. It is, however, with his star catalogues and other later communications to which your attention must be drawn. The catalogues of double stars which he has given us amount to no less than nineteen containing 1,274 new double stars, a number which far exceeds those discovered by any one observer.

Burnham's first catalogue of new double stars, published in 1873, consisted of 81 pairs, which were discovered with a 6-inch Alvan Clark refractor at Chicago, and occupied his time from 1870 to 1872. The distances of the doubles in this, as in several of his first catalogues, were estimations and not exact measurements, his telescope not being furnished with a micrometer. It may here be incidentally remarked that, during the discovery of some of these pairs, he was in communication with Dembowski, who measured many of them, whilst others were measured by our Fellow, Mr. Knott, and appear in his catalogue. The measures by Dembowski were not published till after this observer's death, and were, comparatively speaking, recently (1888) printed by the *Reale Accademia dei Lincei* at Rome. The first catalogue contains several pairs which are very difficult to see with a 6-inch, even when they are known to be doubles. For instance

Number in Catalogue.	Magnitudes.	Distances. ″
4	7 and 7½	0.5
13	8 " 12	1.0
63	6 " 12	0.7

Burnham's second catalogue contained twenty-five new double stars, and was like the first published by this Society in its *Monthly Notices* and in the same year, viz., 1873. The 6-inch was still his instrument, and the class of star is about the same, as will be seen from the following examples:

Number in Catalogue.	Magnitudes.	Distances. ″
89	9 and 9	0.6
96	6 " 14	2.5
104	7 " 12	2.5

His third catalogue contained seventy-six new doubles, and was also published in 1873. In this Burnham began to impose restrictions on his observations, rejecting distances exceeding 5″ and faint pairs below the ninth magnitude when not connected with a brighter star. He thus early appears to have grasped the true idea of weeding out, instead of cataloguing, useless or uninteresting pairs. The four following stars are from this catalogue:

Number in Catalogue.	Magnitudes.	Distances.
120 ν Scorpii	4 and 8	0.3
138	7½ " 10	1.0
141	7½ " 8½	0.4
151 β Delphini	3½ " 5	0.7

This catalogue is important, as containing a class of double star peculiar to Burnham's catalogues. I refer to pairs where the principal star is a naked-eye star, and the companion close and faint.

In the pair ν Scorpii, the principal star is one of the 4th magnitude and the companion of the 8th magnitude, at a distance of less than half a second; the discovery of this pair is a remarkable feat with a 6-inch, and the more so as another companion to ν Scorpii had been measured by many observers before, and the chief component must have been well scrutinized. Burnham says, "I examined it several times under the most favorable circumstances, but could not get rid of an apparent elongation of the principal star in a direction nearly north and south. I requested Professor C. A. Young to examine it with the splendid 9.4-inch Clark refractor of the Dartmouth College Observatory. He examined it several times, and at last when the air was very steady he was rather inclined to think it double, although he could not even notch it." This star was early known as a wide pair, and Jacob at Madras in 1847 found the companion was also double. The close pair was in 1874 measured with the 26-inch Washington refractor, and by Dembowski.

From what has been said, it must be evident that Burnham has a remarkable acuteness of vision, and an eye wonderfully free from defects such as astigmatism, which would render observations such as these impracticable.

The fourth catalogue was published in the *Monthly Notices*, June, 1874. The fifth catalogue has 71 more new pairs, and brings out a peculiar characteristic of your medallist. If a star disc deviated an almost infinitesimal quantity from the circular, his eye detected it at once. In 1874 at Washington, on the night of August 11, he scanned some of his old discoveries, with the result that he made an addition of 14 new pairs to his list. I give one instance. No. 291 in the catalogue had on some occasion offended his critical eye when looking at it through the 6-inch, so he turned the 26-inch on it and found it consisted of two 8½-magnitude stars separated by a distance of only 0″.2. Turning, by chance, the telescope on to 34 Pegasi its mystery also disappeared, for a faint companion 2″ south was discovered.

In 1870, when your medallist began his work, very little was

being done in discovering new doubles. Most observers were contented with the catalogues of the Struves and Herschel, and, so far as I can gather, he had no intention to add largely to these catalogues. His acute eye, however, rendered it impossible for him to stop. His small, though very perfect, instrument was the means of breaking through that resolution, if he had formed one. As already mentioned, Mr. Burnham has added a new class of double stars—viz., naked-eye stars with faint companions. The more difficult of these were discovered with the 36-inch Lick refractor, and have already become interesting. Out of the 1,274 new double stars which he has discovered, 197 are naked-eye stars, not previously known to be double. Of the 1,274 no fewer than 120 have been proved to be physically connected by later measures. He has found new components to 113 old pairs, as follows:

W. Struve (Mensura Micrometricæ)	47
O. Struve (Pulkova Catalogue)	14
W. Herschel	14
J. Herschel	22
South	9
South and Herschel	7

When Mr. Burnham had the use of the 15½-inch* refractor of the Dearborn Observatory, his catalogue still showed that the maximum dividing power was what he sought, and a star from his eleventh* catalogue will exemplify this. In this catalogue was β Scorpii of the second magnitude, with a companion of the tenth magnitude, distant only 0.8″. Even *he* considered it a very difficult pair, and, up to that time, far beyond any close pair discovered, in the inequality of its components. No second-class instrument, however large, would show its duplicity.

In the same catalogue are

	Magnitudes.	Distances. ″
η Cygni	4.5 and 13	7.2
52 Hydræ	5.0 " 11	4.0
54 Herculis	5 " 12.5	2.6

When the great 36-inch telescope was placed at his command, he determined to still further restrict the class of star to be measured, and in selecting stars for his working catalogue, he gave the preference to such as could not or would not be observed elsewhere, leaving the easier systems to others. Speaking generally, I am informed that the most difficult to observe are the most interesting, and but for the care he bestowed on the most difficult of the old systems, as well as those of his own discovery, a serious gap would have occurred in the measures.

* This should read 18½-inch refractor, and eleventh should read thirteenth.—Ed.

An idea of the recent catalogues may be derived from an analysis of his eighteenth, which contains the numbers β 1225 to β 1266, that is, 42 pairs.

	Distances. ″	Pairs.	
Under	1	15	
Between	1 and 2	13	
"	2 " 3	7	42
Above	3	7	

As specimens may be cited

Numbers.	Distances. ″	Magnitudes.
1226	0.40	8.5 and 10.5
1240	0.15	5.6 " 6.0
1241	0.53	5.9 " 10.0

The faintness of the companions and the small distances of the recent Burnham pairs, indicate interesting researches for the possessor of the most powerful telescopes.

In all, your medallist, as before said, has published nineteen catalogues, containing 1,274 pairs, and I believe I am correct in saying that still one more catalogue is in the press, for I learn that the proof sheets of some 250 pages have left his hands for publication. These, it may be presumed, contain observations made at the Lick Observatory.

Of the 1,274 stars already published,

			″	
123	pairs are	under	0.5	apart.
230	"	between	0.5 and 1	"
370	"	"	1 " 2	"
168	"	"	2 " 3	"
178	"	"	3 " 6	"
205	"	over	6	"

Thus, of all known pairs whose distance is under 1″, Mr. Burnham has added more than one half.

We must also note that, besides the measures of his new stars, we are indebted to him for many thousands of measures of previously known doubles.

Not only is Mr. Burnham an original observer, but he is a critic as well. He criticised the catalogue of Sir J. Herschel in a paper in the *Monthly Notices* in 1873.

Nor did the Bedford Catalogue escape his searching scrutiny. A paper in 1880, June, in the *Monthly Notices* dealt with it somewhat severely. But all his criticisms have had the object of correcting and pointing out errors. His paper on the Trapezium of Orion is an example of this. He shows that the minute stars which were said to lie within it and to be visible with small tele-

scopes are, to say the least, mythical. It has only been with the 36-inch Lick telescope that any minute stars have been found, and these would be invisible in any telescope less than a 30-inch.

Not less excellent work has been carried out by your medallist in calculating the orbits of binaries; and, as an examble of the original way in which he sets to work, one has only to refer to his paper in the *Monthly Notices* of April, 1891, on the Orbit of the Companion of Sirius. It may be mentioned that he was the last to obtain measures of the companion of Sirius in 1890. In 1891 he failed to detect it with the 36-inch Lick telescope. With these last observations before him, he re-computed the orbit, and found a period for it shorter than those of Gore or Howard, his period being 53 years, whilst theirs were 58.47 and 57.02 respectively. Should this orbit be correct, the companion should be again visible this year.

Of double stars discovered by Burnham which have short periods, the following are some of the most remarkable:

	Period.	Period Determined by
$\varkappa$ Pegasi β 989	11.37	Burnham
β 883	16.35	Glasenapp
85 Pegasi = β 733	17.48	"
β Delphini = β 151	22.97	"
9 Argus = β 101	23.3	Burnham
β 416	24.7	"
20 Persei = β 524	27.7	"
β 612	30.0	Glasenapp

It appears that there are only two other binaries whose known periods are less than 25 years. I may interpolate here a word as to a second most valuable paper on invisible double stars, in the same number of the *Monthly Notices* in which his paper on Sirius appears, as it indicates well his critical capabilities. In it he treats of the irregularities in the measures of certain double stars. These irregularities have been ascribed to the presence of a dark body in the system, and in some suggestive diagrams Mr. Burnham indicates his opinions on the subject. The double-star orbits which he has found, besides those named, are:

Double-Star Orbits. S. W. Burnham.

Σ 1785 (*Astr. and Ast.-Phys.*, May, 1893).			
20 Persei (β 524) in	*Astr. and*	*Ast.-Phys.*,	May 1893.
9 Argus, β 101	"	"	June 1893.
70 Ophiuchi	"	"	Aug. 1893.
OΣ 285	"	"	"
6 Eridani	"	"	"
37 Pegasi	"	"	Oct. 1893.
95 Ceti	"	"	"

It may here be noted that Burnham, in his astronomical career,

has used a variety of telescopes—the 6-inch his first, a 9.4-inch at Dartmouth, the 12-inch Lick, the 15½-inch Washburn, the 18½-inch Chicago, the 26-inch Washington, the 36-inch Lick. With him, increase of aperture available meant a further refinement in his researches, and a further power for interesting work.

The catalogues of the double stars and of orbits calculated by Burnham are a formidable work to have been accomplished by any one man; but when it is remembered that this is the more serious phase of his labors, and does not include much of what one might almost characterize as a lighter character which he has contributed to astronomy, it seems almost impossible to realize that it lay within the capacity of any one individual. The *English Mechanic*, the *Monthly Notices and Memoirs of the R. A. S.*, the *Astronomische Nachrichten*, the *American Journal of Science*, ASTRONOMY AND ASTRO-PHYSICS, *Knowledge*, the *Sidereal Messenger*, the *Observatory*, and various other papers have been enriched by his contributions. The line of work that he laid himself out to accomplish he has successfully carried through. It is not of that showy or dramatic order which attracts universal attention, or gives occasion for newspaper paragraphs. It is, however, as arduous as it is unpretending, and when more than twenty years have been devoted to it, and when the success which has attended it has been so remarkable, it does honor to the Society to recognize the high estimation in which it holds this work by awarding to its author the greatest distinction it can confer.

Mr. Burnham is an amateur in the true sense of the word. Born about 1840, as far as I can learn, he adopted the vocation of stenographer, and it was not till he had chosen his profession that his mind was fortunately directed to the study of astronomy. What his first toy telescope may have been I know not; but from the time when he secured his 6-inch Clark, he made the progress in the direction which he had determined to follow. By day he followed his regular calling, whilst by night he studied the heavens till (as an article in *The Century* informs us) "daylight drove him to bed." In 1874 he became a Fellow of this Society, being nominated by his friend the late Rev. T. W. Webb, an astronomer to whose well known book, apparently, Burnham was indebted for the turn which his astronomical labors were to take. In 1876 Burnham was appointed Director of the Chicago Observatory, a post which he held for a short time, though he subsequently had the use of the 18½-inch telescope at that observatory. In 1879 when the trustees of Lick Observatory had chosen Mt. Hamilton as the site on which to build their Observatory, he

was selected on the recommendation of Professor Newcomb to report on the atmospheric and other conditions of that locality, and subsequently observed the transit of *Mercury* from the same spot in conjunction with Professor Holden. This connection with Mt. Hamilton was not destined to cease, for he was appointed to a post in the Lick Observatory, where he turned the magnificent telescope of that institution to good account in his researches. Lately he retired from the position occupied there and resumed his work at Chicago, and holds the position of Professor of Practical Astronomy at that University. It is to be hoped that he will be only temporarily absent from an established Observatory; for, if rumor is to be believed, he is to be Astronomer to the Yerkes Observatory, where the great 40-inch telescope is to be erected. If this be so, the choice made by the trustees is an honor to him and to themselves.

I think, gentlemen, I have said enough to convince you that the medal has been worthily bestowed and well earned, and in handing it to our honored foriegn secretary, Dr. Huggins, to transmit to him, I would ask him at the same time to convey a message from the Royal Astronomical Society "in Annual Meeting assembled," wishing Mr. Burnham health and strength to continue his contributions to astronomical science, and expressing their gratitude to him for what he has done for it in the past.—*Monthly Notices.*

THE ORBIT OF 9 ARGUS.*

S. W. BURNHAM.

In the issue of ASTRONOMY AND ASTRO-PHYSICS for June, 1893, I give the results of an investigation of the orbit of 9 Argus (β 101) and predicted that in the two years following the date of my last measures at Mt. Hamilton (1892.05) the angular motion of the companion would be about 180°, and that at the beginning of the present year the position-angle would be a little more than 270°.

In order to ascertain whether or not the apparent ellipse shown in the paper referred to, which depended entirely on my last measures with the 36-inch refractor, I requested Professor Barnard to make a set of measures with the same instrument,

* Communicated by the author.

and to carefully note the quadrant of the smaller component. I have received from him the following observations:

		°	″
	1893.920	278.9	0.52
	.939	285.8	0.40
	.961	281.6	0.40
	1894.153	282.8	0.37
	.189	280.8	0.48
	.192	282.4	0.42
Mean	1894.06	282.0	0.43

The smaller star was noted as being certainly on the preceding side. It will be seen that this position conforms very closely to the ellipse I have given. The angular motion is a little greater than that predicted, and consequently the distance is a trifle larger, but the difference is only 0″.07, and the agreement on the whole is entirely satisfactory.

In the paper referred to, I found a period of 23.3 years. The later measures appear to indicate that this time may be still further reduced, but as the observations of next year will give more accurate data for whatever correction may be necessary, it does not seem worth while at this time to obtain another provisional orbit.

THE SATELLITE OF NEPTUNE.*

F. TISSERAND.†

Less than a month after Galle had discoved Neptune‡ in the place assigned to it by the calculations of Le Verrier, the English astronomer Lassell suspected the existence of a small satellite, and verified it with certainty in 1847. This body gives little light, for it is only of the fourteenth magnitude, and it requires a very powerful telescope to render it visible. According to the photometric determinations of Pickering it would be, however, as large as our moon; but it is about 12,000 times more distant from us, so we understand why it is so faint.

When its orbit was calculated it was found that the satellite had a retrograde movement around the planet; this is more marked than that already known concerning the satellites of Uranus; from this point of view the two planets, the most distant of our system, present a striking contrast to the others.

* Translated from *L'Astronomie*, March, 1894.

† Director of the Observatory of Paris.

‡ Neptune was searched for and found by Galle from the calculations of Le Verrier, Sept. 27, 1846; the satellite was discovered by Lassell Oct. 10, following.

We know to-day that Mars has two satellites, Jupiter four, Saturn eight and Uranus four. One might suppose that Neptune would have more than one. Several times searches have been made with powerful telescopes, notably with that at Washington; but no new satellite has been found.

Lassell's satellite appears to be an unique body in the solar system, in this respect, that its very great distance from the Sun must protect it from perturbations having their origin on this side. On the other hand it is not troubled by neighboring satellites; it seems that it should present a movement of the greatest simplicity, realizing rigorously the geometric motion of Kepler. So some astronomers have proposed to make it a sort of touchstone to verify the uniformity of certain movements in the planetary system; it would constitute a time-keeper of great precision, to which no cause of derangement could be foreseen.

The accumulated observations, however, have shown that this is not true.

Mr. Marth, the English astronomer who occupies himself with the ephemerides of satellites, called attention some five or six years ago, to a singular fact; the observations from 1852 to 1883 show that the plane of the orbit of the satellite of Neptune is slowly shifting, in the same direction and by an appreciable amount, for, during these 31 years its inclination to the plane of Neptune's orbit has increased about 5°, aud this difference is too great to be accounted for by errors of observation. On the other hand the observations made by Mr. H. Struve, with the great refractor at Pulkova, during the last ten years, confirms the direction and the amouut of displacement of the orbit. What can be the cause of this trouble?

We have not hesitated to attribute it to the flattening of the planet. This flattening has escaped, up to the present time, direct measures, and it will escape without doubt for a long time yet. The reason is that the disc of Neptune subtends to us only a small angle of about two seconds, and if the flattening is small, $\frac{1}{100}$ for example, the ellipticity of the disc will be imperceptible.

But, in order to account for the derangement established by the observations, another thing is necessary. If, indeed, the plane of the orbit of the satellite coincided with the equator of the planet, there would be no reason for this coincidence not maintaining itself indefinitely. It is necessary, then, that the two planes make a considerable angle with each other and it is demonstrated that in this case the first of the two planes is displaced with reference to the second in such a manner, that the angle, which it makes, always retains the same value.

If we imagine on the celestial sphere the poles of these two planes, the first describes, with uniform motion, a small circle around the second, so that, when we shall have the observations of two or three centuries, we will be able to trace this circle quite exactly, and obtaining its pole will find the north pole of the planet, which direct observation has been incapable of doing. The data which are at our disposal to-day are insufficient; however, it seems to us probable that the angle of which we have spoken should be from 20 to 25 degrees, and the flattening less than $\frac{1}{100}$. Mr. Newcomb, without making detailed calculations, has assigned the same cause to the phenomenon.

The fifth satellite of Jupiter, discovered so unexpectedly by Barnard in 1893, should show a displacement produced by the same cause. It does not appear that the four large satellites of Galileo are appreciably disturbed in this way; here again it is necessary to have in mind the flattening of the planet, which is considerable in the case of Jupiter. But this flattening produces another effect; it cannot modify the position of the plane of the satellite's orbit, since this small body moves in the plane of the equator; but it can make this orbit turn in its plane, and the calculation shows that it should make a complete revolution of the orbit in about five months. If, then, the orbit is not rigorously circular, but is much or little excentric, it must happen that at a certain time the satellite will recede farther from the planet on the west side than on the east. This is what Barnard has already established. But we can say that 75 days later the inverse will occur; it will be nearest on the west side. I hope that the observations will confirm this prediction if the orbit is at all elliptic.

The effect of which we have spoken should also be produced for the satellite of Neptune, but it is a great deal less pronounced than the change of the plane of the orbit; nevertheless, it will not be long until it is established.

SUNSPOT OBSERVATIONS AT GOODSELL OBSERVATORY.*

H. C. WILSON.

Visual observations of the Sun were begun at Goodsell Observatory in May, 1889, and were continued with few interruptions, save from cloudy weather, until August 20, 1892, when the 8-inch equatorial which was employed for this work was dismounted

* Abstract of introduction to Publication No. 3 of Goodsell Observatory of Carleton College, Northfield, Minn.

for repairs and important modifications. When the remodeled instrument was mounted, in May, 1893, the photographs obtained with it were so excellent, that it seemed useless to continue the visual observations, since the same results could be more easily obtained from the photographs. It has been thought best therefore to publish this series of observations separately, in the hope that it may be of use to investigators in Solar Physics, extending as it does from about a minimum well on toward a maximum of the Sun-spot period.

The observations consisted in counting once each day, preferably near noon, the number of groups of spots, the number of spots in all the groups and the number of faculæ or groups of faculæ visible on the solar disc. The state of the seeing was indicated by noting whether or not the granulation of the solar surface was visible.

The instrument employed was usually the 8-inch equatorial by Alvan Clark & Sons. In the first part of the series a diagonal eyepiece with a neutral tint shade was used. Later, when photographs were being taken regularly, in order to avoid changing the adjustments, the image of the Sun was projected through the photographic combination of lenses, objective and enlarging, on a screen of white paper. This projected image was about 6 inches in diameter and the spots were easily seen and counted, but the faculæ were not quite so well seen as by the direct method.

Photographs of the Sun.

The 8-inch equatorial was provided with a third objective lens, correcting it for the photographic rays of light, in 1887, but it had no enlarging apparatus and no means of making the extremely short exposures necessary for a successful photograph of the Sun. In 1889 an enlarging apparatus was improvised out of an ordinary wide field negative eyepiece and the adapter provided for use in stellar photography. A very convenient and rapid little shutter was made by a local amateur photographer, Dr. H. L. Cruttenden. This was attached to the eyepiece where the emerging pencil of rays was about one-fourth of an inch in diameter. The slide of the shutter was made from a light piece of zinc, two inches long and three-fourths of an inch wide and had a run of one inch. A slit one-half an inch long and a fiftieth of an inch in width was cut across the center of the slide. Later the slit was formed by two pieces of black paper pasted upon the zinc. These were cut from the same piece and laid with the corresponding edges in juxtaposition, so that irregularities in one

edge were matched by opposite ones in the other, and the slit was everywhere of the same width, although the edges were not necessarily straight. The width of the slit, after many experiments, was put at one one-hundredth of an inch, greater width giving over-exposure. The slide was propelled by rubber bands capable of giving it the run of an inch in less than a tenth of a second, so that the exposure for each ray in the pencil of light was less than one thousandth part of a second. The slide was touched off by means of a rubber air bulb and piston. The whole apparatus was so light that no perceptible vibration was produced and it was in every way satisfactory except that the enlarged image was not in a plane and therefore could not all be brought into focus on the photographic plate. The average diameter of the solar image upon the plate was three and one-half inches, and of this the central three inches was in fairly good focus, while the edge was poorly defined.

With this apparatus photographs of the Sun were taken during 1889 and 1890 whenever spots of any considerable size were visible. After July, 1891, they were taken daily when possible. The time of each photograph was noted to the nearest minute.

The sensitive plates used at first were Seed No. 20. Later these could not be obtained and we used Seed No. 22. These also went out of market and toward the last Seed No. 23 were used. Recently we have been using Carbutt's Keystone A plates, sensitometer No. 10, with much more satisfactory results.

A line parallel to the equator was photographed upon each plate, by means of a thread stretched across the tube just in front of the plate. This thread was adjusted parallel to the equator and tested by allowing a sunspot to drift along it when near the meridian. This adjustment once made was changed only when necessary because the photographic attachments had been taken off in order to use the telescope for other purposes.

In 1892 we were able to purchase new enlarging lenses, made especially for the purpose by Messrs. Hastings and Brashear. In order to use these it was necessary to remodel the mounting of the telescope and therefore discontinue the photographs for several months.

The new apparatus gives images of the Sun either three and one-fourth or seven and one-half inches in diameter. The smaller sized image is very sharp in all parts and capable of very accurate measurement. The larger image is not quite plane but is only slightly out of focus toward the edges. Photographs of the smaller size are now being taken daily and we hope soon to have apparatus for measuring them accurately.

Measures of the Photographs.

The measures, the results of which are contained in this volume, were made with the aid of a mica scale made by the writer. On a sheet of clear mica, 5 × 6 inches, a series of concentric circles were ruled with a pair of fine pointed steel compasses, the radial measurements being taken from a chronograph scale which was accurately ruled for us by Mr. G. N. Saegmuller. Radial lines were drawn at every tenth degree of the circumference. The radial scale was approximately 1 division = 1.5 mm. On the average 54 of these divisions covered the diameter of the solar image.

The measures were made by laying this scale, ruled side down, upon the film side of the negative, making the 90° — 270° diameter parallel to the equatorial line, centering the solar image within the circle nearest to its circumference, and reading from the scale the position angle and distance of each spot from the center. The scale reading for the edge of the solar disc was read at the same time, this being necessarily the same for all points of the limb except where distortion resulted from refraction. In all cases it was easy to get the average radius.

For the measures the negative was placed in a wooden frame, a little larger than the mica scale, so that the latter could be easily adjusted and held to it. This frame was then held toward a strong light and one person read off the positions and diameters of the spots, while another recorded the readings. This process is extremely rapid and surprisingly accurate for such a simple apparatus. The positions and dimensions of all the spots at all prominent on the most spotted plate can be read off in from five to ten minutes. The maximum error of the scale is one-tenth of a division or about 0°.2 of arc on the solar surface, at the center of the disc. The maximum error of reading the scale is about the same, so that the combined error of scale and reading may be as large as perhaps 0°.5 of longitude at the center of the disc. This error becomes 1°.0 at 65° distance from the center and at the edge of the disk might amount to as much as 5°.0 of longitude. The position angles were read to the nearest half degree so that the maximum error in these and the resulting latitudes at the edge of the disk is about 0°.5.

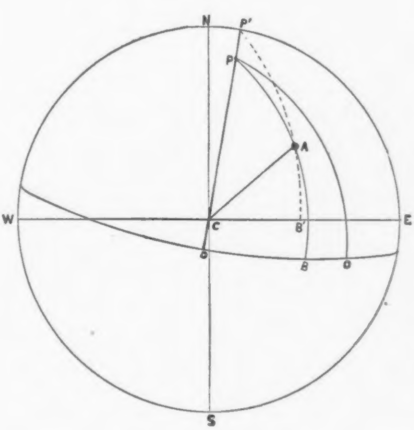
These limits of accuracy are amply sufficient for the study of the distribution of sunspots and for the study of their larger movements. For the great majority of spots, too, the changes in form from day to day are such that it is impossible to identify the same portions of them within the above limits.

For the areas of the spots the average diameters of the penumbræ were estimated. Allowance for foreshortening of spots near the limb was partly made by taking the diameter parallel to the limb.

Reduction of the Measures.

The method of reduction was made as nearly as possible consistent with the accuracy of the measures. The corrections for parallax and refraction were wholly neglected, the former being wholly insignificant, the latter amounting to 0°.1 only when the Sun was within 15° and to 0°.2 within 8° of the horizon, below which altitudes no photographs were taken. Auxiliary tables were prepared which rendered the reductions very easy and rapid, those for a single spot occupying a skilled computer from one to two minutes of time. These tables were prepared in the following manner.

Fig. 1.



In Fig. 1 let A be the position of a spot upon the solar disc, and C the center of the disc; N, E, S, W represent the north, east, south and west points of the solar image as seen upon the film side of the plate. Let the scale reading for the distance CA be r and that for the radius of the image CE, CN, CS or CW be R. Represent the arc on the solar surface corresponding to AC by s and the angle at the Earth subtended by the same line by s', then

$$AC = \frac{r}{R} = \sin(s + s')$$

and

$$s = \sin^{-1}\frac{r}{R} - s' \tag{1}$$

The maximum value of s' will be the apparent solar radius which averages 16′ or 0°.3, and

$$s' : 16' :: r : R \text{ or } s' = \frac{r\,0.^\circ 3}{R} \qquad (2)$$

A table was prepared from formulæ (1) and (2) giving s for every unit of r and for every tenth of unit of R between the extreme scale readings on the edge of the disc. For those values of r which fell between R and $R - 1.0$ the table was extended to tenths of units of r.

Again in Fig. 1 let P be the position of the north pole of rotation, PO the assumed zero meridian for the reckoning of longitudes, and DBO the solar equator. Represent the position-angles of the spot and the north pole of rotation from the north point of the disc by p and P, the heliographic longitude and latitude of the spot by l and d, and those of the center of the disc by L and D; then

$$\begin{aligned} p &= NCA \\ P &= NCP \\ L &= OPC \\ D &= \text{arc } CD \\ l &= OPA \\ d &= \text{arc } AB \end{aligned}$$

The quantities P, D and L were taken from the tables published annually in "The Companion to the Observatory" a publication edited by the astronomers at the *Royal Observatory, Greenwich,* from which we take also the following statement:

"In computing D the inclination of the Sun's axis to the ecliptic has been assumed to be 82° 45′, and the longitude of the ascending node to be 74° 20′. In computing L the Sun's period of rotation has been assumed to be 25.38 days, and the meridian which passed through the ascending node at the epoch 1854.0 has been taken as the zero meridian."

These tables were interpolated to noon of each day at this Observatory and were thus very convenient in use.

In order to find l and d it is necessary to solve the spherical triangle ACP for each spot. We have the following general equations:

$$\begin{aligned} \cos PA &= \cos PC \cos CA + \sin PC \sin CA \cos PCA \\ \sin PA \cos APC &= \sin PC \cos CA - \cos PC \sin CA \cos PCA \\ \sin PA \sin APC &= \sin CA \sin PCA \end{aligned}$$

By the proper substitutions these become

$$\begin{aligned} \sin d &= \sin D \cos s + \cos D \sin s \cos (p - P) \\ \cos (L - l) \cos d &= \cos D \cos s - \sin D \sin s \cos (p - P) \qquad (3) \\ \sin (L - l) \cos d &= \sin s \sin (p - P) \end{aligned}$$

To adapt these to logarithmic computation let

$$\begin{aligned} k \sin \psi &= \sin s \cos (p - P) \\ k \cos \psi &= \cos s \end{aligned} \qquad (4)$$

then

$$\begin{aligned} \sin d &= k \sin (D + \psi) \\ \cos (L - l) \cos d &= k \cos (D + \psi) \\ \sin (L - l) \cos d &= \sin s \sin (p - P) \end{aligned} \qquad (5)$$

The formulæ to be used in making an accurate reduction are (1), (2), (4) and (5), and in many cases we have used them in order to verify the tables. Ordinarily we have used tables prepared from formulæ (3) in the following manner.

As D is always a small angle, or arc, its maximum value being only a little over 7°, it may be treated as a differential quantity, and its effect upon the quantities d and l may be obtained by differentiating equations (3). This process gives

$$\begin{aligned} &\cos d \, \Delta d = \{\cos D \cos s - \sin D \sin s \cos (p - P)\} \Delta D \\ &\sin (L - l) \cos d \, \Delta l - \cos (L - l) \sin d \, \Delta d \\ &\qquad = - \{\sin D \cos s - \cos D \sin s \cos (p - P)\} \Delta D \\ &\cos (L - l) \cos d \, \Delta l + \sin (L - l) \sin d \, \Delta d = 0 \end{aligned} \qquad (6)$$

If now in equations (3) we put $D = 0°$ they become

$$\begin{aligned} \sin d_0 &= \sin s \cos (p - P) \\ \cos (L - l_0) \cos d_0 &= \cos s \\ \sin (L - l_0) \cos d_0 &= \sin s \sin (p - P) \end{aligned} \qquad (7)$$

This is equivalent to placing the north pole of the Sun at P' instead of P.

Putting $D = 0°$ in (6) we have

$$\begin{aligned} &\cos d_0 \, \Delta d = \cos s \, \Delta D \\ &\sin (L - l_0) \cos d_0 \, \Delta l - \cos (L - l_0) \sin d_0 \, \Delta d \\ &\qquad = - \sin s \cos (p - P) \, \Delta D \\ &\cos (L - l_0) \cos d_0 \, \Delta l + \sin (L - l_0) \sin d_0 \, \Delta d = 0 \end{aligned} \qquad (8)$$

Substituting from (7) the values of the right hand members of (8) and solving for Δd and Δl we obtain

$$\begin{aligned} \Delta d &= \cos (L - l_0) \, \Delta D \\ \Delta l &= - \sin (L - l_0) \tan d_0 \, \Delta D \end{aligned} \qquad (9)$$

Then for any variation of D from 0° we will have

$$\begin{aligned} \Delta D &= D - 0° = D \\ d &= d_0 + \Delta d \\ l &= L - (L - l_0) + \Delta l \end{aligned} \qquad (10)$$

The quantities d_0 and $(L - l_0)$ were computed by equations (7) for every 5° of s and $(p - P)$ and tabulated with the horizontal argument s and vertical argument $(p - P)$. The quantities computed for one quadrant serve for the others by the proper arrangement of the arguments $(p - P)$ and the signs of the tabular numbers.

The corrections Δd and Δl were tabulated by means of equations (9), the former for every 10° of $(L - l_0)$ and every degree of D, and the latter with the three arguments, $(L - l_0)$, and d_0 to every 10° and D to every degree.

The areas of spots were taken from a table prepared by means of the formula

$$A = \frac{a^2}{8R^2}$$

in which a is the measured diameter of the spot and R the measured radius of the Sun. A is expressed in millionths of the visible hemisphere of the Sun.

By means of these tables the reduction of a single spot measure is reduced to the following steps:

1. Take from Table I the quantities P, D and L.
2. With the measured radii r and R take s from Table II.
3. Subtract P from p.
4. With arguments s and $(p - P)$ take $(L - l_0)$ from Table III and d_0 from Table IV.
5. With arguments $(L - l_0)$, d_0 and D take Δl from Table V and Δd from Table VI.
6. Subtract $(L - l_0)$ from L.
7. Add Δl and Δd to l_0 and d_0.
8. Take A from Table VII with arguments a and R.

More rigorous values of Δl and Δd may be obtained by performing step 5 a second time, using as arguments $(L - l_0 - \frac{1}{2}\Delta l)$, $d_0 + \frac{1}{2}\Delta d$ and D, but this second approximation will usually be unnecessary.

When there are many measures to be reduced the work is expedited by performing each step for a large number of measures at once.

Comparison with the Greenwich Results.

The latest volume of the Greenwich Spectroscopic and Photographic Results at hand is that for 1890. A comparison of the few measures made on common dates in that year is given in the following table, in which Δl and Δd are the corrections required


120
110
100
90
80
70
60
50
40
30
20
10
0
18
JA

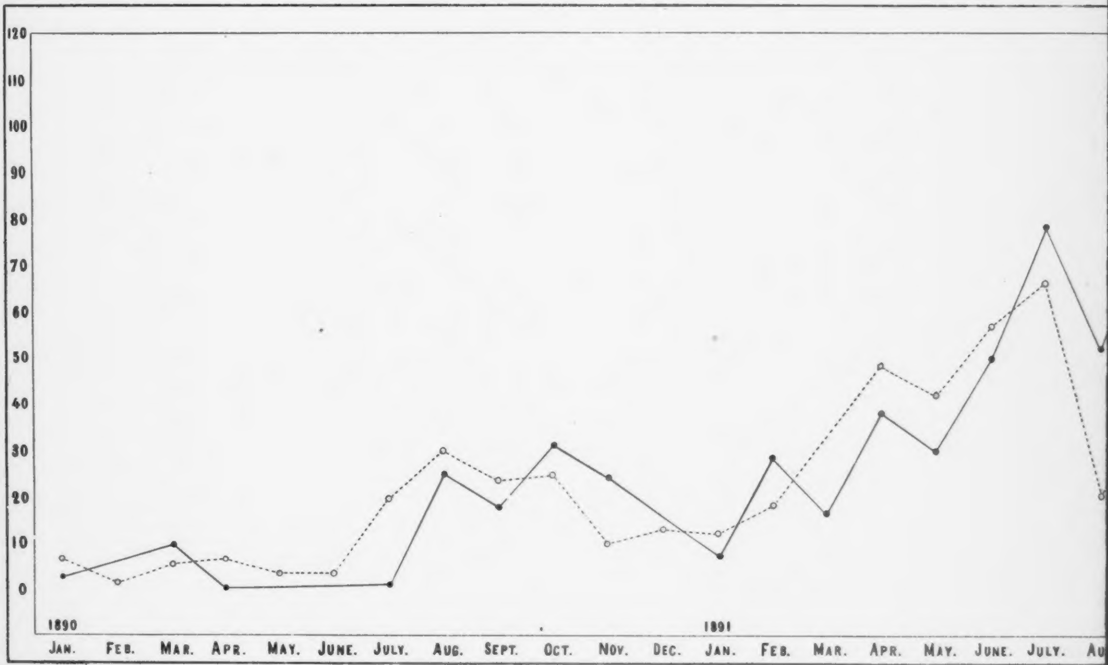
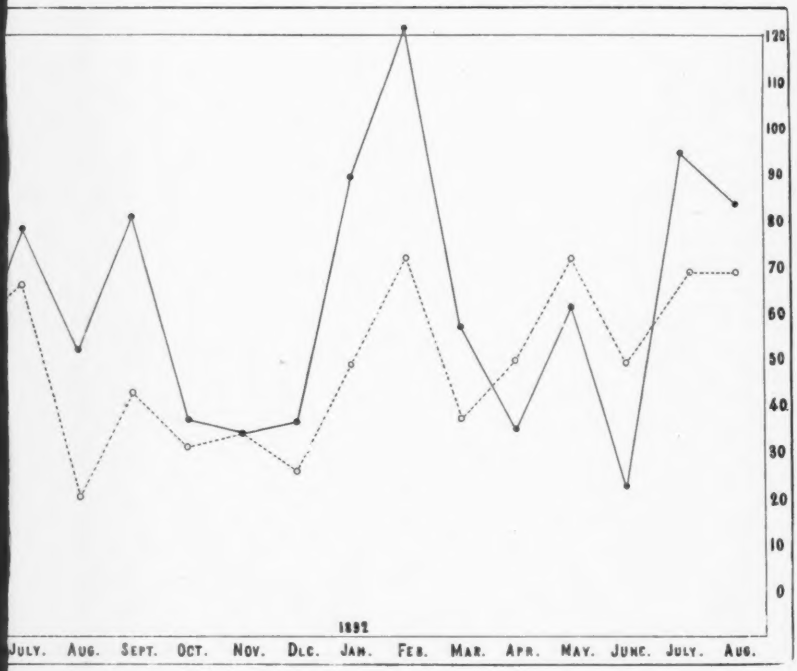


FIG 2. DIAGRAM SHOWING THE CHANGE OF THE AVERAGE DAILY

THE DOTTED LINE REPRESENTS THE NUMBERS, THE F



DAILY NUMBER AND AREA OF SUNSPOTS.
THE FULL LINE THE AREA.

to reduce our measures to those made at Greenwich. In several cases the spots were very irregular and it is evident that in measuring the photographs the observers did not take the same portions of the spots. The average difference taken regardless of signs, is 0°.91 for *l* and 0°.53 for *d*. This is larger than the average differences between our own measures of the same spots on different days and shows, probably, that the errors due to personality in locating the point for measurement in the spot are greater than those due to the method of measurement and reduction.

Date.			Group.	$L-l$	l	d	Δl	Δd
				°	°	°	°	°
1890	Sept.	9	18	+ 13.0	264.6	+ 22.0	− 1.3	+ 0.7
		23	19	+ 44.0	48.2	+ 21.8	− 0.5	+ 0.5
		27	..	+ 1.1	39.3	+ 21.5	+ 0.2	0.0
			..	+ 4.1	36.3	+ 20.3	+ 0.1	+ 0.3
			..	+ 6.3	34.1	+ 21.5	− 0.8	+ 1.2
	Oct.	20	20	+ 62.8	35.4	− 22.2	− 1.3	− 0.1
			..	+ 67.8	30.0	− 23.1		
		21	..	+ 48.6	35.2	− 21.3	− 0.6	− 0.9
			..	+ 50.9	32.9	− 19.1	− 0.9	− 1.7
			..	+ 56.4	27.4	− 23.1	+ 1.2	− 0.5
		22	..	+ 33.8	35.4	− 20.0	+ 1.3	− 0.2
			..	+ 37.1	32.1	− 18.8		
			..	+ 42.0	27.2	− 22.7	+ 1.3	+ 0.5
		23	..	+ 21.6	35.9	− 21.4	− 0.9	− 0.9
			..	+ 24.6	32.9	− 19.6	− 1.1	− 0.8
			..	+ 30.2	27.3	− 23.8	0.0	− 0.7
			22	+ 30.0	27.5	− 4.9	− 1.7	− 0.5
	Nov.	26	23	+ 7.8	320.6	+ 18.8	− 0.9	+ 0.1
			..	+ 14.8	313.6	+ 17.9	− 0.6	+ 0.2
			..	+ 15.2	313.2	+ 20.8	− 2.1	0.0
			..	+ 23.2	305.2	+ 22.4	− 0.5	+ 0.2

Summary of the Observations.

In the following tables the columns are self explanatory, with the exception of the last. This column gives the average area per day of all the spots, on the days when photographs were taken, and on the days when photographs were not taken because no spots were visible. The areas are expressed in millionths of the area of the visible hemisphere of the Sun.

The progress of the average daily numbers and areas of spots is shown graphically in Fig. 2, the dotted line representing the daily number of spots, and the smooth line the areas. In order to plot them to the same scale the daily numbers were multiplied by 3 and the areas divided by 10. Although the fluctuations are quite marked, especially in July, 1891, and February and June, 1892, there is a pretty steady increase in both the number and area, during the period of two and a half years, which might-be

quite fairly represented by a straight line. As a rule the number and area change together.

Year.	Month.	No. of Days of Visual Obs.	Average No. of Groups.	Average No. of Spots.	No. of days when no Spots were seen.	No of days when photographs were taken.	Average total area of Spots.
1889	May	3	0.3	0.3	2		
	June	9	0.6	3.0	4	4	.000295
	July	4	0.8	6.5	2		
	Aug.	20	1.3	7.0	4	12	348
	Sept.	18	0.8	1.5	8	8	101
	Oct.	9	0.3	0.6	6		
	Nov.	0					
	Dec.	6	1.5	12.7	2	2	112
1890	Jan.	13	0.7	2.2	7	2	26
	Feb.	14	0.3	0.5	9		
	March	10	0.5	1.8	5	4	100
	April	15	0.4	2.1	10	1	4
	May	12	0.5	1.2	7		
	June	13	0.2	1.2	10		
	July	14	1.1	6.6	3	2	10
	Aug.	19	1.0	10.0	6	4	253
	Sept.	13	1.2	8.0	3	6	180
	Oct.	10	1.2	8.4	3	5	314
	Nov.	15	0.5	3.4	7	3	244
	Dec.	15	1.0	4.5	3		
1891	Jan.	13	1.0	4.1	5	2	74
	Feb.	4	1.2	6.2	0	4	286
	March	1	0.0	0.0	1	2	166
	April	13	2.2	16.1	0	3	380
	May	16	3.6	14.1	0	8	300
	June	4	3.8	19.0	0	4	498
	July	14	3.0	22.1	0	10	783
	Aug.	22	2.8	6.8	0	19	522
	Sept.	18	3.9	14.2	0	18	809
	Oct.	16	3.3	10.4	0	16	367
	Nov.	14	3.4	11.3	0	12	339
	Dec.	15	2.4	8.7	0	14	361
1892	Jan.	21	5.3	16.3	0	21	894
	Feb.	11	4.5	24.0	0	12	1218
	Mar.	16	3.6	12.3	0	17	571
	April	15	5.1	16.7	0	16	350
	May	14	4.7	24.0	0	14	614
	June	20	5.1	16.4	0	19	226
	July	23	5.0	23.0	0	23	945
	Aug.	18	6.9	23.0	0	20	835

Distribution in Latitude of Sunspots.

Latitude.	Number of Groups.					Area of all Groups.				
	1889	1890	1891	1892	Total	1889	1890	1891	1892	Total
°										
+ 35	0	0	0	0	0	0	0	0	0	0
30	0	1	5	1	7	0	241	1149	331	1721
25	0	1	13	12	26	0	2	2234	1775	4011
20	0	4	30	15	49	0	2077	7055	1565	10697
15	0	1	17	15	33	0	204	4169	2570	6943
10	0	0	3	18	21	0	0	181	5408	5589
+ 5	0	1	0	2	3	0	2	0	6	8
0	0	0	0	0	0	0	0	0	0	0
− 5	1	1	0	2	4	542	7	0	43	592
10	3	0	2	7	12	826	0	327	799	1952
15	0	0	2	15	17	0	0	1192	2073	3265
20	2	3	11	23	39	915	637	4090	3493	9135
25	2	1	2	16	21	357	2	1051	2158	3568
30	0	0	1	8	9	0	0	16	3854	3870
− 35	0	0	0	0	0	0	0	0	0	0

In this table the latitudes include 2°.5 on each side of the number given. The area of each group was taken on the day when it was nearest the center of the disc except in a few cases when there was so great change that some other date would give more nearly its maximum area. The totals for the four years clearly indicate the maximum number and area of spots at about latitude 20° north and south. The secondary maximum at — 30° in 1892 was produced by the extraordinary group of February. In the same year a remarkably large number of groups occurred in latitude + 10°, producing maxima for the year in that latitude in both the number and total area of groups. The preponderance of the number of groups in the southern hemisphere over that in the northern hemisphere of the Sun in 1889 has been remarked by other observers. The results here given for that year are too meager to be of much weight. Summing the results in north and south latitudes we see that in 1890 the greater number and greater area of spots were on the northern hemisphere. The same was true in 1891 but in 1892 the spottedness of both hemispheres was about the same.

Year	No of Photographs.	No. of groups. North.	No. of groups. South.	Total Area. North.	Total Area. South.
1889	26	0	8	.000000	.002640
1890	27	8	5	.002526	.000646
1891	122	68	18	.014788	.006676
1892	142	63	62	.011655	.012420

Distribution in Longitude of Sunspots.

A similar study of the distribution of sun-spots in longitude' revealed no tendency toward the continued recurrence of groups in the same longitudes for periods of more than a few months, the maxima for one year often coinciding in longitude with the minima for the next. In this investigation the spots in north and south latitudes were considered separately and together. The great solar disturbances during the period 1889–1892 occurred in longitudes 30° — 40°, 80° — 90°, 150° — 160°, 180°, 200° and 220° — 230° in the northern hemisphere, and 30°—40°, 80°, 160°, 250° — 270°, and 280° in the southern hemisphere.

The Great Group of February, 1892.

We have not attempted to study the movements of the spots, except in the case of the great group, No. 136, of February, 1892. This group was remarkable for the great extent of the disturbed area, it being the largest that has occurred for many years. Its passage across the central meridian of the Sun was accompanied on the Earth by a violent magnetic storm and a brilliant display of the aurora borealis. Measures of the photograph of Feb. 11 when the group was near the center of the Sun's disc give for the dimensions of the single large penumbra 72,000 by 33,000 miles, while the total disturbed area was 135,000 miles long by 80,000 miles wide.

The changes in the details of the group were so rapid that it is difficult to identify the same spots from day to day. There were two large and very black umbræ, *A* and *B*, surrounded by a large penumbra, which marked two notable centers of disturbance. Their apparent motions were quite different, as will appear from Fig. 3, in which the longitudes and latitudes on the different dates are plotted. The spot *A* moved due east, decreasing about 10° in longitude during the interval Feb. 5 to 16. The spot *B* in the same time described a looped curve, changing from a position due north of *A* to one almost due west of the latter. The great penumbra surrounding these two centers shared the rotary motion thus indicated. The spots *C* and *D* were separate from the great penumbra and did not share in its motion. Each divided into two parts between Feb. 9 and 11, or a new spot developed in the rear of each.

The cyclonic movement of the spot *B* is more clearly shown if we reduce the longitudes to a given date, applying corrections for the variation of the period of rotation with the latitude.

The longitudes were determined with Carrington's rotation period 25.38 days. Carrington, however, found that the period varied for spots in different latitudes, the apparent daily motions being represented approximately by the formula

$$\Delta l = 865' - 165' \sin^{\frac{7}{4}} d$$

in which d represents the latitude and Δl the daily motion in longitude from the center of the Sun's disc. Faye found from the same observations

$$\Delta l = 862' - 186' \sin^2 d.$$

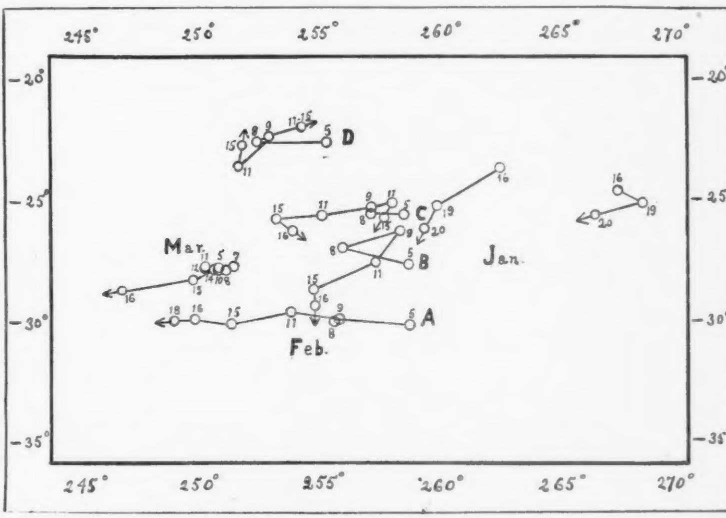


Fig. 3.—Apparent Movements of the Principal Umbræ of the Great Sun-spot Group of February 1892.

The period 25.38 days corresponds to a daily motion of 851′. The daily correction, therefore, required to reduce the longitude of a spot to the period corresponding to its own latitude is, according to Faye,

$$\Delta_1 l = 11' - 186' \sin^2 d.$$

Reducing the longitudes of the four spots A, B, C and D, to the date Feb. 11 by this formula, we have the following results, in which d is the latitude, l the longitude by the 25.38 day period and l_1 the longitude reduced to Feb. 11.

	A			*B*		
	d	*l*	l_1	*d*	*l*	l_1
	°	°	°	°	°	°
Feb. 5	− 30.2	259.1	255.6	− 27.7	259.1	256.1
8	− 30.0	256.0	254.2	− 27.0	256.4	254.9
9	− 29.9	256.3	255.1	− 26.2	258.8	257.8
11	− 29.6	254.2	254.2	− 27.6	257.7	257.7
15	− 30.1	251.7	254.0	− 28.7	255.1	257.1
16	− 29.9	250.1	253.0	− 29.3	255.2	256.7
18	− 30.0	249.3	253.4			

	C			*D*		
	d	*l*	l_1	*d*	*l*	l_1
	°	°	°	°	°	°
Feb. 5	− 25.7	260.0	257.6	− 23.1	255.9	254.2
8	− 25.5	257.7	256.5	− 22.6	252.8	252.0
9	− 25.2	258.5	257.7	− 22.5	253.3	252.7
11	− 25.4	257.7	257.7	− 22.2	254.7	254.7
	− 25.7	255.6	255.6	− 23.6	252.0	252.0
15	− 25.8	258.2	259.6	− 22.2	254.8	255.9
	− 25.8	255.3	255.3	− 22.9	252.2	253.3
16	− 26.4	254.4	256.4			

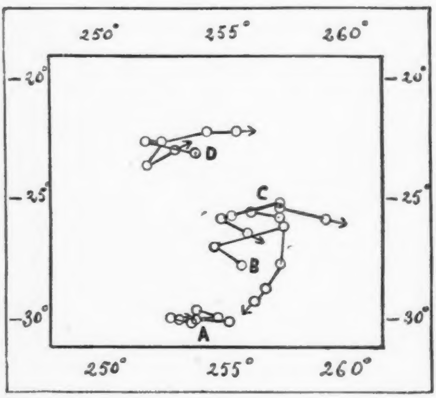


Fig. 4.

The positions thus corrected have been plotted in Fig. 4. The displacement of *A* has, by this process, been reduced to an amount which may, perhaps, be accounted for by the errors of measurement. The spot *B*, however, takes on a decided cyclonic curve. The large displacement between Feb. 8 and 9 is not a displacement of the umbra as a whole, bu rather results from a change in its form. As shown by the photographs the blackest part changed from the east to the west end of the umbra between these dates.

In tracing the history of this group of spots we find, in November, the group No. 96 in longitude 255° — 265° and latitude — 19°. Again, in December, group No. 105 with principal centers in longitude 268°, 282° and 286°, latitude — 19°. In January there was a single round spot in longitude 278°, latitude — 25°, until the 16th, when there were found two new large spots, a little east of the single one, showing evidence of violent disturbance of the solar surface. These may be considered the beginning of the February group. Their apparent courses from Jan. 16 to 20 are shown in Fig. 3.

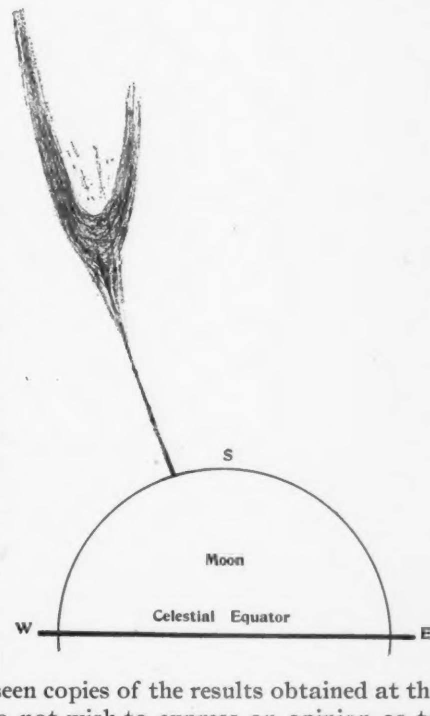
At its reappearance in March the group was much changed and none of its prominent spots can be identified with individual spots of the February group. The most prominent umbra was in the latitude of *B*. Its apparent course during the interval March 5 to 16 is shown in Fig. 3.

A COMETARY STRUCTURE IN THE CORONA OF APRIL 16, 1893.

J. M. SCHAEBERLE.

In the October number of this journal I called attention to a comet-like structure near the Sun during the total eclipse of last April, as shown on all the Lick Observatory photographs of the outer corona.

The form and position of this object is shown in accompanying sketch. The straight, slender, nearly radial streamer, from the Moon's outline to the structure in question, is conspicuously visible and distinctly isolated from the more inclined neighboring streamers not shown in the sketch. The drawing is made from an original negative taken with the 40 ft. telescope. On the Dallmeyer negatives the tail-end of the structure, which for the 40-ft. telescope falls outside of the limits of the 18 × 22 inch plate, can be traced for more than a degree from the nucleus or head of the object. Until I have seen copies of the results obtained at the other eclipse stations, I do not wish to express an opinion as to the true nature of this object. Copies of our own photographs were distributed more than eight months ago, but repeated requests for copies of the results obtained at the other stations have thus far been in vain.



LICK OBSERVATORY, March 16, 1893.

MELTING OF THE POLAR CAPS OF MARS.*

WILLIAM H. PICKERING.

In ASTRONOMY AND ASTRO-PHYSICS for 1892, p. 668, is given an account of a series of conspicuous changes that were observed upon the surface of Mars at the time of the melting of its southern snow cap. These changes were so marked that many of them could be readily observed this year with any moderately large telescope, although the position of the planet at this time will be much more unfavorable than was the case in 1892. In that year upon July 12 a central branch made its appearance in the peak of the Y mark. This branch would lie just south of Noachis upon Schiaparelli's map. It was soon seen that this central branch formed a portion of a dark line connecting the great split in the southern snow cap with the Northern Sea. This sea lies in the northern portion of the Syrtis major, and is much darker than any of the surrounding regions. Immediately upon the formation of this connecting link, a series of striking changes occurred in the shape and color of the regions surrounding the Northern Sea. These changes are fully described in the article referred to above, and no further description of them is necessary in this connection. The apparent alterations from night to night were very marked, and the whole series of changes was completed inside of two weeks.

The point to which I wish to call the attention of astronomers at the present time is that upon May 30, 1894, Mars will reach the same portion of its orbit with regard to the Sun that it did upon July 12, 1892. It is therefore presumable that a similar series of changes will occur about that date. As Mars will be morning star at this period, rising about midnight, and will at the same time, be rather remote, it is not likely that there will be many observers watching it, and for this reason every available observation will be of much greater value than it would be under other circumstances. The center of the Northern Sea, longitude 290°, is central May 30d, $17^h.5$ E. S. T., therefore if the expected changes occur on time this year the eastern astronomers must look for them chiefly by daylight, while the western astronomers may look for them rather earlier in the morning. There is no reason, however, for expecting any meteorological phenomenon to occur on precisely the same date upon two successive years, and should the thaw begin earlier this year upon Mars than it did last, it will be to the advantage of the eastern astronomer.

CAMBRIDGE, MASS., March 22, 1894.

* Contributed by the author.

Astro-Physics

ON A COMBINATION OF PRISMS FOR STELLAR SPECTROSCOPE.*

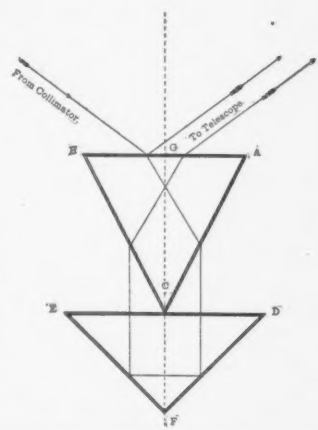
H. F. NEWALL.

The arrangement of prisms which is the subject of this note, has not, so far as I am aware, been described before, and its conveniences for astronomical purposes in particular are so numerous that I propose to give some details concerning it.

ABC is a strongly dispersing prism; all three faces are accurately worked, and the angles at A and B are equal.

DEF is an ordinary double total reflection prism.

These two prisms are relatively fixed as shown in the accompanying section with the faces A B and DE parallel (or approximately so; see final paragraph); the edges of the prisms are also parallel and further the edges C and F lie in a plane GCF which passes through the middle, G, of the face AB and is perpendicular to AB.



Prisms relatively fixed; the combination capable of rotation about G.

The combination thus formed is symmetrical about the plane GCF, and is made capable of being turned about an axis which is the intersection of the plane GCF with the face AB. Thus in the figure the section turns in the plane of the paper round G.

Light from a collimator falls on the face AB as indicated in the figure, (the *central* ray, however, falls on G), and the incidence is suitably adjusted by turning the combination about G; the usual telescope is adjusted to view the spectrum. The light from the collimator suffers deviation and dispersion in passing through the prism of refracting angle A; it is then twice reflected within the reflecting prism and again suffers deviation and dispersion in passing through the prism of refracting angle B.

The spectrum seen with the telescope is therefore similar to what would be seen in a two-prism spectroscope whose prisms

* (Read on 29 Jan., 1894, before the Cambridge Philosophical Society, England.) Communicated by the author.

were of the same material as that used for the prism ABC and had angles equal to A and B respectively.

The telescope receives, when it and the prism-combination are properly adjusted, not only the light which has passed *through* the combination, but also the light reflected from the face AB at primitive incidence. The reflected light gives rise to a simple image of the slit which appears to be superposed on the spectrum; for ease in description and for an obvious reason this will be called the 'pointer.' If the prism combination is turned through a small angle $\delta\theta$, the pointer moves through the angle $2\delta\theta$, but the spectrum moves through a much smaller angle, whose magnitude varies with the part of the spectrum considered. Hence the pointer can be made to coincide with any line in the spectrum, and its change of position is known in terms of the corresponding change of position of the prism-combination. If, therefore, a suitable micrometer movement is used to move the prisms the position of the pointer may be read off the micrometer.

The line in the spectrum which coincides with the pointer is always that which is due to rays which have passed symetrically through the prism combination. The movement of the prisms gives symetrical passage to different rays in turn, and the pointer indicates which ray has passed symetrically. The course of rays which pass symetrically through the combination is shown in the figure; such rays emerge from the face AC in a direction parallel to the plane of symmetry, GCF, and consequently the deviation in passing through the prism A is equal to the angle of primitive incidence:

$$D = \varphi = \varphi + \psi - A;$$

whence $A = \psi$, or the angle of emergence from the face AC is equal to the angle A. The angle of emergence can be made under readily calculable conditions, equal to the angle of primitive incidence, but generally only with rigid accuracy for rays of one refrangibility; hence the rays which pass symetrically will not in general pass with absolute minimum deviation.

The pointer may be considered as being connected with the prism and independent of the observing telescope. It is thus attached, so to speak, to the strongest part of the instrument instead of the weakest, where the micrometer is usually placed, namely the eye-end of the telescope. The telescope is used merely as a magnifyer. The need for carefully worked surfaces for the prisms forms perhaps the strongest objection to the use of this combination; curvature in any one surface of either prism must

throw the pointer and spectrum into different focal planes in the observing telescope and so introduce parallax difficulties which can only be eliminated by reworking the faulty surface. Two prisms which I have in my possession and which were worked by Hilger, have been used to test the capabilities of the combination and give excellent results.

The observing telescope is pointed towards G and is mounted so as to turn about the same axis through G as that about which the prisms turn; this single motion is enough to bring every part of the spectrum in turn into view. Thus the advantages of a two-prism spectroscope are obtained without the disadvantages arising from the usual double adjustment necessary in directing the observing telescope. The combination which I describe may therefore replace a grating in a diffraction spectroscope.

If a bright star is observed, both spectrum and pointer are bright; for a faint star, the brightness of the pointer is appropriately subdued. The fact that the brightness of the pointer maintains a suitable proportion to the brightness of the spectrum to be investigated is a great convenience.

In astronomical work, the object glass of an equatorial is used to throw an image of the star, whose spectrum is to be studied on the slit of the spectroscope. If the slit is widened, the image of the star itself is seen in place of the pointer. This is a great convenience, inasmuch as in most cases the star may be thus identified. When the star is recognized amongst its neighbors, the slit is closed to a suitable width and the pointer then appears as a short narrow line in the spectrum. In practice it is preferable to have the pointer not actually superposed on the spectrum, but displaced so as to be a little above or below the spectrum. This end may be attained by slightly tilting the reflecting prism.

OBSERVATIONS OF THE NEW STAR IN NORMA.*

W. W. CAMPBELL.

Observations of the new star in Norma were first attempted here February 13th, 18^h. The star was found without difficulty, although its true altitude when on the meridian is less than 2½ degrees. Its light was estimated at one-fifth or one-sixth that of the 8 mag. star A. G. C. 10940. The Nova would therefore be of the 9½ or 10 magnitude.

* Communicated by the author.

Its spectrum consisted of an exceedingly faint continuous spectrum in the yellow and green, and four bright lines apparently identical in position and relative intensity with the bright lines 575, 501, 496, and 486 in the August, 1892, spectrum of Nova Aurigæ. Rough measures of the wave-lengths of the two brightest lines, made after daylight, gave 5013 and 4953.

The star was seen again for a few minutes between clouds on February 28th, 17^h. Its magnitude remained unchanged at about 9½. The faint line in the yellow was not seen with certainty this morning, possibly owing to light clouds. Two hasty settings of the micrometer wire upon each of the three bright lines in the green and blue gave the following intervals:

1st. (intensity 10) – 2nd. (intensity 3) = 49 tenth metres;
2nd. (intensity 3) – 3d. (intensity 1) = 100 " "

Keeler's intervals for the nebular lines are respectively 48.0 and 97.5 tenth-metres.

On March 2d, $16^h 30^m$, the star was seen, magnitude unchanged, but fogging of the object glass prevented measures. The transparency of our atmosphere is shown by the fact that neighboring stars were visible down to about the 9.5 magnitude in the 4-inch finder, though the Nova could not be seen with certainty.

March 6th, 16^h. A hazy sky made the spectrum very faint. Eight micrometer comparisons with the adjacent lead line gave the wave-length 5007.3 for the principal Nova line. These different settings on the second Nova line gave for it the wave-length 4957. The third line, $H\beta$, was too faint for observation. Magnitude of star unchanged.

There can be no doubt that the spectrum of Nova Normæ is nebular.

Lick Observatory, 1894, March 7.

RESULTS OF SOLAR OBSERVATIONS MADE AT THE ROYAL ROMAN COLLEGE IN THE FOURTH QUARTER OF THE YEAR 1893.*

P. TACCHINI.

I have the honor to send you the results of our solar observations for the fourth quarter of the year 1893. In November the weather was not very favorable, but in October and December it was really splendid.

* Communicated by the author.

1893	Days of observation.	Relative Frequency of Spots	Relative Frequency of days without spots.	Relative Size of Spots	Relative Size of Faculæ	No. of groups per day.
October	27	26.85	0.00	112.7	89.2	7.4
November	20	23.15	0.00	96.4	84.0	5.4
December	27	33.89	0.00	166.4	86.0	8.0

The phenomena of the spots, although still of considerable frequency, have suffered some diminution in comparison with the preceding quarter. It is well to note the secondary maximum in the month of December, for after the other maximum in the month of August, the spots continued to diminish until some time in November. In the period of maximum solar activity, the Sun has always appeared with spots and large pores (trous). Following are the results of the observations of protuberances:

1893	Days of observation.	Protuberances: Average number	Average height	Average breadth
			″	°
October	22	5.82	36.2	1.9
November	13	5.00	34.7	1.8
December	23	6.48	35.5	1.9

The observations show, therefore, that the phenomena of the protuberances have undergone a diminution. It should be noted, however, that a secondary maximum occurs in the month of December, as in the case of the spots, and that a similar coincidence occurred in the month of August. The only protuberance worthy of special note was observed on the 26th of December, in position angle 288°. Its variations in height are shown in the following table:

h	m		″
11	20	height =	87.8
11	41		133.0
11	47		141.1
11	54		79.8
12	0		66.5

The maximum apparent velocity of ascent was 26 kilometres per second; of descent, 109 kilometres. At 278° there was another protuberance, the height of which at $11^h\ 22^m$ was 109″, and which at $11^h\ 48^m$ had entirely disappeared. No metallic lines were observed in the spectrum of the limb of the Sun at the place of the two prominences; the maximum solar activity is therefore quite different in character from what it was before. The spots at the limbs of the Sun appear almost always in a state of quiescence, and it is probably for this reason that on the Earth we have had no strong magnetic disturbances or remarkable auroras.

ROME, Feb. 15, 1894.

ON THE VISUAL APPEARANCE OF NOVA AURIGAE.

WILLIAM HUGGINS.

Some discussion has taken place as to the visual appearance of this object since it was re-observed in the autumn of 1892. At the Lick Observatory and also at Pulkowa, the Nova was seen to differ in appearance from a star of similar magnitude, and to have taken on the appearance of a small bright nebula consisting of a nucleus surrounded with a pretty bright and dense nebulosity 3″ in diameter (A. N. 3118, p. 408, and 3184, p. 263).

Mr. Newall, on the contrary, observing with the 25-inch Newall refractor at Cambridge on Sept. 14th, 1892, says: "With a power of 215 I, at first, thought that the Nova was diffuse and resembled a planetary nebula rather than a star; but on focussing more carefully I made out that the Nova was distinctly stellar; now, however, the neighbouring stars resembled planetary nebulæ. In fact the Nova and neighboring stars could not be focussed simultaneously. The Nova owes its visual magnitude nearly entirely to the light that gives rise to the three green lines, and it was possible to verify a conclusion drawn from this fact and from the nature of the chromatic dispersion of a refractor 29 feet focal length; the image of the Nova was distinctly more point-like than that of the neighbouring bright star when each in turn was focussed as carefully as possible." (*Nature*, vol. 46, p. 489).

Dr. Roberts photographed the star on Oct. 3d, 1892, with an exposure of 110 minutes; and on Dec. 25th, 1892, with an exposure of 20 minutes; the diameters of the photo-images being 21″ and 13″ respectively. Dr. Roberts concludes, "there is no indication of nebulosity round the Nova or in its vicinity. It appears as sharply defined as the other stars." (*Monthly Not.* vol. LIII, p. 123.)

Professor Vogel still maintains (A. N. 3198, p. 76) as an explanation of the nebulous appearance seen at the Lick Observatory and at Pulkowa, the view which he suggested in his paper "*Ueber den neuen Stern in Fuhrmann*" (*Abhandl. d. Kgl. Akad. d. Wissensch.* Berlin, 1893, p. 46): "*dass die beobachteten Hüllen um den Stern nichts anderes als die chromatischen Abweichungskreise gewesen sind.*"

It may therefore be of interest for me to state the results of a careful scrutiny of the image of the Nova in a reflecting telescope which gives very fine definition. This telescope has an aperture of 18 inches, with both mirrors of speculum metal arranged in

the Cassegrain form. Mrs. Huggins and myself on Jan. 12th, 1894, compared the image of the Nova with that of the small star 85″ *n, f,* which was only a little less bright, observing with a series of eye-pieces magnifying from 100 up to about 700 diameters. The Nova, which of course, came to focus absolutely with the star, presented always an appearance precisely similar. We remarked particularly that with the highest power the image was as small and as sharply defined a point as that of the star. On the night of Jan. 12th, definition was excellent here; and beyond all doubt under the conditions above described, the Nova appeared as a true star.—*Observatory* for March, p. 108.

LONDON, S. W., 90 Upper Tulse Hill, 1894, Jan. 18.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects, properly included in ASTRO-PHYSICS, should be addressed to George E. Hale, Kenwood Observatory of the University of Chicago, Chicago, U. S. A. Authors of papers are requested to refer to last page for information in regard to illustrations, reprint copies, etc.

Note on Nova Aurigæ.—I have just made the interesting discovery that Nova Aurigæ appears on a plate which I exposed Jan. 5, 1892, on the north coast of Norway, for the purpose of photographing the northern light. It has been my intention for a long time to look over my plates with this object in view, but on account of other affairs I have but just now been able to undertake the work.

Unfortunately, the Nova is near one edge of the plate; χ Aurigæ is not on it at all. The Nova is however fairly distinct, since stars below the eighth magnitude can sometimes be recognized without great difficulty. The photograph was taken on an orthochromatic plate, sensitive to yellowish green light. Martin Brendel, Greifswald, 1893, Dec. 9. [Translated from *A. N.* 3209].

Reproduction of Astronomical Photographs.—The *Observatory* and the *Journal of the British Astronomical Association* reproduce some of the photographs of the corona taken by Professor Schaeberle in South America on April 16, 1893, but any one who has seen Professor Schaeberle's beautiful negatives will hardly find these reproductions satisfactory, as the detail of the inner corona is wholly lost. The difficulty is one inherent in photographic processes. Strong contrasts can be successfully dealt with, but an attempt to reproduce photographs of nebulæ or of the corona, in which delicate gradations of light occur, generally results in failure. Professor Holden, writing on methods of representing the Milky Way, in No. 34 of the *Publications of the Astronomical Society of the Pacific,* says, "If drawings are reproduced by photography, the very first copy on a sensitive plate changes all the contrasts of the original design. It is usual to send this first negative to the person who is to make the process block for printing, and who must make another copy on a 'stripping plate,' or on something equivalent. These stripping plates are usually very slow, and the contrasts are again much

changed by the transfer. Finally, the block is made, and in the course of printing the impressions new changes of contrast come in, not to speak of great losses of definition. If the original is a negative, and not a drawing, difficulties of precisely the same sort are present. Definition is always lost and the contrasts are always changed, more or less. Our experience at the Lick Observatory has been considerable, and we have found reproductions by heliogravure (on copper) to be the most satisfactory. They are hardly more than twice as expensive as the best 'processes,' and they are very much superior."

As original negatives of astronomical subjects can find their way into the hands of comparatively few persons, the question of satisfactory methods of reproduction is one of very considerable importance. Mr. Ranyard is doing valuable service by publishing in nearly every number of *Knowledge* really beautiful plates representing the latest triumphs of astronomical photography.

An Astronomical Expedition to Arizona from Harvard College Observatory.*—A party in charge of Professor W. H. Pickering will soon set out from Harvard College Observatory, to establish an observing station somewhere in the state of Arizona, the principal object of the expedition being to observe Mars during the favorable opposition next summer. For the following details we are principally indebted to an article in the *Boston Herald*.

The success of the observing station at Arequipa has induced Professor Pickering to make the experiment of founding a similar station at a high altitude somewhere within the limits of the United States. Trial on Pike's Peak showed that the "seeing" was not good there, (in this respect agreeing with the experience of Professor Hale), and preference has been given to the dry climate and clear skies of Arizona. The exact location has not yet been decided upon, as it has been thought best to make some preliminary tests with a small instrument. Mr. A. E. Douglass will take a six-inch telescope for this purpose to Prescott, Phoenix and Tucson, and the site chosen will depend upon his report.

The chief instrument of the expedition will be a fine eighteen-inch refractor by Brashear, the objective of which was exhibited at Chicago. Mr. Brashear will also provide a serviceable mounting and many of the accessories.

It is stated that the funds for the expedition have been generously provided by Mr. Percival Lowell of Boston, a gentleman who is deeply interested in astronomy, and has contributed to its literature. Mr. Lowell will himself accompany the expedition as an observer.

Stonyhurst College Observatory.—The latest publication of this Observatory consists mainly of meteorological observations. We learn however, in the introduction, that the objective of the Father Perry Memorial telescope arrived in the beginning of November, and was placed in position on the 6th. It has a clear aperture of 14⅞ inches, was made by Sir Howard Grubb, and although the atmospheric conditions have not yet been sufficiently perfect for a complete test of its defining powers, is undoubtedly of the highest excellence. This telescope is mounted on the pier of the old eight-inch telescope which it replaced, the pier being so massive that it carries the new and much larger telescope without difficulty.

Since May, 1893, all clear nights have been devoted to a photographic study of the spectrum of β Lyræ. The results have been published in the *Monthly Notices* of the Royal Astronomieal Society (Dec. 1893).

* This expedition will not be under the direction of Harvard College Observatory, but under that of private parties.—Ed.]

New Telescope for Greenwich Observatory.—An editorial note in the *Observatory* says:—"We have reason to know that Sir Henry Thompson, the eminent surgeon, has offered the magnificent sum of 5,000 pounds sterling to the nation, through the Astronomer Royal, for the purpose of buying a telescope for Greenwich Observatory. It is not often astronomy finds such a generous patron, on this side of the Atlantic at least, and moreover, one who can so well appreciate the exact needs of the science at the moment. For Sir H. Thompson foreseeing that the astronomy of the future is to be photographic, and feeling that England should be well equipped in this arm, makes it a condition of his gift that the telescope is to be expressly designed for photographic purposes. So far as the plans are made, and subject to the acceptance of the offer by the government, the instrument is to be of 26-inches aperture, just twice that of the telescope used for the Photographic Chart of the Heavens—in fact the instrument (which will probably be made by Sir H. Grubb) is to be made from the model of Astrographic Equatorial, but of exactly double the demensions in every particular. The guiding telescope for the new instrument will be the 12¾-inch Merz refractor with a light tube; and the 9-inch photographic objective presented by Sir H. Thompson to the Royal Observatory some three years ago will also be carried on the same mounting for use as a photoheliograph as at present.

The new instrument, when completed, will be housed under the Lassell Dome, on the top of the central octagon of the new Physical Observatory, now being built in the south grounds of the Royal Observatory.

Anderson's Variable in Andromeda.—The variability of Anderson's star in Andromeda has been confirmed by Professor Pickering. The star appears on eight plates made at Harvard College Observatory and from these the maximum photographic brightness has been determined to be 9.0 while other plates show that the minimum is below 12 mag. The Harvard photographs and the observations quoted by Dr. Anderson as having been made at Bonn and Cambridge are satisfied by a period of 281 days. A maximum occurred on March 30, 1894.

A remarkable feature of this star, according to Professor Pickering, is the uniformity of the variation of its light. During the three months following the maximum the diminution in light expressed in magnitudes was perfectly uniform, and at the rate of one magnitude in 25 days. The increase during the three months preceding the maximum was also uniform, and at the rate of one magnitude in 26 days. The magnitude at minimum brightness, assuming these laws to hold throughout the period of variation, would be 14.5.

In a note following Professor Pickering's article in *A. N.* 3213, Dr. Hartwig gives a few observations which lead him to think that the period of the star may be 74.4 days, but they are not sufficiently numerous to justify a difinite conclusion.

Mr. Hadden's Solar Work—From recent private letter we learn of Mr. David E. Hadden's recent work with the spectroscope. He says: "I am now in possession of a very good two-inch grating by Mr. Brashear, and am much interested in spectroscopic observation, especially in noting the reversals of the C line in the umbra of the large spot now on the Sun's surface (Feb. 23). I have also secured some fairly good photographs of the Sun showing the large group now visible with a photoheliograph of my own construction. I am using a 3-inch Jena glass visual objective (Brashear) and enlarging lens at focus, and secure photographs about two and one half inches in diameter."

CURRENT CELESTIAL PHENOMENA.

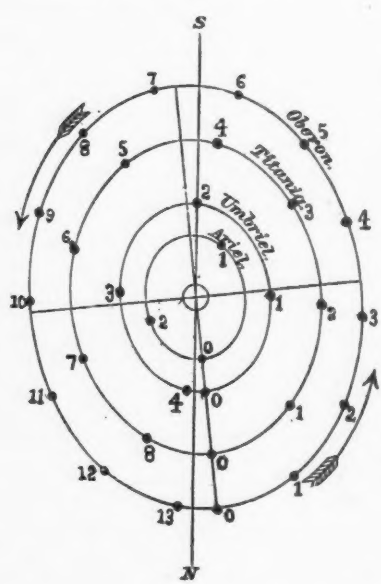
PLANET NOTES FOR MAY.

Mercury will be at superior conjunction, *i. e.*, behind the Sun, May 20 at 9^h 44^m central time. During May this planet will be wholly hidden to the eye by the glare of the Sun, although it is calculated to reach its greatest brilliancy on the 23d.

Venus will be in good position for observation about 4 o'clock in the morning during May. Her phase will increase from about half to two-thirds during the month, while her brilliancy will diminish in the ratio of 137 to 97 in the same time, because of her recession from the Earth. Venus and the waning Moon will be in conjunction May 1st at 5^h 07^m P. M. central time and again May 31 at 3^h P. M.

Mars is also to be observed in the morning. He is about 30° west and 14° south from Venus, in the constellation Capricorn and will move northeast into Aquarius during May. At the end of the month he will be found about half way between the first magnitude stars Fomalhaut (*α Piscis Austrini*) and Markab (*α Pegasi*). Mars will be in conjunction with the Moon March 28 at 2^h 18^m central time. Observers in Central and South America may see the planet occulted at this time.

Jupiter and *Neptune* will be too low in the west during the early evening hours for any satisfactory observations during this month. The tables of the satellites are therefore omitted. On Poole Bros. map for this month, however, the courses of Jupiter and Neptune among the stars are indicated for the six months from April 1 to Sept. 1.



APPARENT ORBITS OF THE SATELLITES OF URANUS IN 1894.

Saturn will be in best position for observation during May, crossing the meridian about 10 o'clock in the first half and 9 o'clock P. M. in the latter half of the month. The rings of Saturn are now pretty well widened out, so that the three parts can be distinguished readily and the Cassini division can be followed all the way around. The elevation of the Earth above the plane of the rings is about 12°. Saturn is in the constellation Virgo about 5° north of the first magnitude star Spica, with which he is almost equal in brightness. A conjunction of the Moon and Saturn occurs May 16 at 10^h 55^m A.M.

Uranus is also in good position for observation, being at opposition May 3. We give this time a diagram showing the apparent courses of the four satellites about the planet. In the tables we give the times when each satellite will be at greatest elongation, that is, at the point 0 on the diagram. The black dots with the numerals beside them indicate the positions of the satellites on the successive dates after the northern elongation. For example, Umbriel will be at northern elongation, *i. e.*, at the point marked 0 on its orbit, May 3 at $8^h.6$ P. M. On May 4 at the same hour it will be at the point marked 1, May 5 at the same hour it will be at 2, etc.

The four oldest of the minor planets, *Ceres, Pallas, Juno* and *Vesta*, all happen to be in the region of sky covered this month by Poole Bros'. map in *Popular Astronomy* and their apparent courses for the next six months are shown in red upon the map. Ceres, Pallas and Vesta have passed the best time for their observation but will all be bright enough to be found without much difficulty during the next three months. Ceres was at opposition March 13. Its brightness will be equal to that of a star of the 7.2 magnitude April 1, 7.5^m May 1, 7.9^m June 1, 8.2^m July 1, 8.5^m August 1, and 8.8^m September 1. Pallas was at opposition Feb. 7. Its brightness will be 7.0^m April 1, 7.6^m May 1, 8.1^m June 1, 8.5^m July 1, 8.8^m Aug. 1, and 9.1^m Sept. 1. Vesta was at opposition March 10. Its brightness will be 6.5^m April 1, 6.8^m May 1, 7.2^m June 1, 7.5^m July 1, 7.8^m Aug. 1 and 7.9^m Sept. 1. Juno is not so favorably situated. Although she comes to opposition May 7 she is so far from her perihelion, or point of nearest approach to the Sun, that she will at brightest be only of the tenth magnitude and will therefore probably not be seen by the amateur.

Planet Tables for May.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
May 5	1 50.6	+ 9 16	4 15 A. M.	10 56.5 A. M.	5 38 P. M.
15	3 06.3	+16 58	4 18 "	11 32.7 "	6 47 "
25	4 35.7	+23 14	4 27 "	12 22.5 P. M.	8 08 "
			VENUS.		
May 5	23 58.4	− 1 15	3 05 A. M.	9 04.5 A. M.	3 04 P. M.
15	0 37.7	+ 2 17	2 51 "	9 04.4 "	3 18 "
25	1 18.2	+ 6 03	2 37 "	9 05.4 "	3 34 "
			MARS.		
May 5	21 58.9	− 14 11	1 58 A. M.	7 05.3 A. M.	12 12 P. M.
15	22 26.0	− 11 55	1 36 "	6 53.1 "	12 10 "
25	22 52.4	− 9 32	1 14 "	6 40.2 "	12 07 "
			JUPITER.		
May 5	4 21.2	+20 59	5 53 A. M.	1 26.5 P. M.	9 00 P. M.
15	4 30.8	+21 22	5 22 "	12 56.8 "	8 32 "
25	4 40.6	+21 43	4 50 "	12 27.2 "	8 04 "
			SATURN.		
May 5	13 18.2	− 5 18	4 39 P. M.	10 22.1 P. M.	4 06 A. M.
15	13 15.9	− 5 05	3 56 "	9 40.5 "	3 25 "
25	13 14.1	− 4 56	3 14 "	8 59.4 "	2 44 "
			URANUS.		
May 5	14 43.6	−15 25	6 45 P. M.	11 47.2 P. M.	4 49 A. M.
15	14 41.9	−15 18	6 04 "	11 06.3 "	4 09 "
25	14 40.4	−15 11	5 22 "	10 25.4 "	3 28 "

NEPTUNE.

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5	4 43.6	+20 50	6 16 A. M.	1 49.1 P. M.	9 22 P. M.
15	4 45.2	+20 52	5 38 "	1 11.2 "	8 44 "
25	4 46.7	+20 55	5 00 "	12 33.4 "	8 07 "

THE SUN.

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5	2 51.0	+16 24	4 44 A. M.	11 56.5 A. M.	7 08 P. M.
15	3 30.0	+18 59	4 32 "	11 56.2 "	7 20 "
25	4 10.0	+21 03	4 23 "	11 56.7 "	7 31 "

THE MOON.

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 2	0 16.4	+ 1 02	3 24 A. M.	9 34.2 A. M.	3 56 P. M.
4	1 58.0	+14 11	3 59 "	11 07.7 "	6 34 "
6	3 56.9	+24 38	4 58 "	12 58.5 P. M.	9 12 "
8	6 13.3	+28 33	6 30 "	3 06.6 "	11 36 "
10	8 27.0	+24 03	9 01 "	5 12.0 "	1 08 A. M.
12	10 21.9	+13 34	11 41 "	6 58.8 "	2 01 "
14	12 02.0	+ 0 43	2 09 P. M.	8 30.7 "	2 38 "
16	13 37.8	−11 49	4 30 "	9 58.4 "	3 15 "
18	15 18.4	−21 56	6 50 "	11 30.9 "	4 03 "
20	17 07.4	−27 42	9 05 "	1 11.6 A. M.	5 15 "
22	18 59.6	−27 51	10 53 "	2 55.8 "	7 01 "
25	20 45.6	−22 38	12 05 A. M.	4 33.6 "	9 10 "
27	22 22.0	−13 24	12 52 "	6 02.1 "	11 23 "
29	23 54.3	− 1 36	1 28 "	7 26.2 "	1 38 P. M.
31	1 31.8	+11 11	2 04 "	8 55.4 "	4 03 "

Phases and Aspects of the Moon.

	Central Time. d	h m
New Moon	May 5	8 42 A. M.
Perigee	" 7	10 24 P. M.
First Quarter	" 12	12 21 A. M.
Full Moon	" 19	10 43 A. M.
Apogee	" 23	6 20 P. M.
Last Quarter	" 27	2 04 P. M.

Elongations of the Satellites of Uranus.

[The diagram shows the apparent form of the satellites of Uranus during the summer of 1894. The black dots with the numerals indicate the positions of the satellites at intervals of 1 day after each northern elongation. The points marked 0 are those of northern elongation.]

ARIEL.

	h	
May 3	11.2 A. M.	N
5	11.7 P. M.	N
8	12.2 P. M.	N
11	12.7 A. M.	N
13	1.2 P. M.	N
16	1.7 A. M.	N
18	2.1 P. M.	N
21	2.6 A. M.	N
23	3.1 P. M.	N
26	3.5 A. M.	N
28	4.0 P. M.	N
31	4.5 A. M.	N

UMBRIEL.

	h	
May 3	8.6 P. M.	N
8	12.1 A. M.	N
12	3.5 "	N
16	7.0 "	N
20	10.5 "	N
24	2.0 P. M.	N
28	5.4 "	N

TITANIA.

	h	
May 2	7.8 P. M.	S
7	4.3 A. M.	N

TITANIA Cont.

	h	
May 11	12.8 P. M.	S
15	9.3 "	N
20	5.8 A. M.	S
24	2.3 P. M.	N
28	10.8 "	S

OBERON.

	h	
May 7	9.8 A. M.	S
14	3.4 "	N
20	9.0 P. M.	S
27	2.7 "	N

Elongations of the Satellites of Saturn.

MIMAS.

		h		
May	1	9.9	P. M.	W
	2	8.5	"	W
	3	7.1	"	W
	4	5.7	"	W
	5	4.3	"	W
	6	2.9	"	W
	8	12.9	A. M.	E
	8	11.5	P. M.	E
	9	10.1	"	E
	10	8.8	"	E
	11	7.4	"	E
	12	6.0	"	E
	13	4.6	"	E
	14	3.2	"	E
	16	1.2	A. M.	W
	16	11.8	P. M.	W
	17	10.4	"	W
	18	9.0	"	W
	19	7.6	"	W
	20	6.2	"	W
	21	4.8	"	W
	22	3.4	"	W
	24	1.4	A. M.	E
	24	12.0	midn.	E
	25	10.6	P. M.	E
	26	9.3	"	E
	27	7.9	"	E
	28	6.5	"	E
	29	5.1	"	E
	30	3.7	"	E

ENCELADUS.

May	2	3.6	P. M.	E
	4	12.5	A. M.	E
	5	9.4	"	E
	6	6.3	P. M.	E
	8	3.1	A. M.	E
	9	12.0	M.	E

ENCELADUS CONT.

		h		
May	10	8.9	P. M.	E
	12	5.8	A. M.	E
	13	2.7	P. M.	E
	14	11.5	"	E
	16	8.4	A. M.	E
	17	5.3	P. M.	E
	19	2.2	A. M.	E
	20	11.1	"	E
	21	7.9	P. M.	E
	23	4.8	A. M.	E
	24	1.7	P. M.	E
	25	10.6	"	E
	27	7.5	A. M.	E
	28	4.3	P. M.	E
	30	1.2	A. M.	E
	31	10.1	A. M.	E

TETHYS.

May	1	9.4	P. M.	E
	3	6.7	"	E
	5	4.0	"	E
	7	1.3	"	E
	9	10.6	A. M.	E
	11	7.9	"	E
	13	5.2	"	E
	15	2.5	"	E
	16	11.8	P. M.	E
	18	9.1	"	E
	20	6.4	"	E
	22	3.7	"	E
	24	1.0	"	E
	26	10.3	A. M.	E
	28	7.6	"	E
	30	4.9	"	E

DIONE.

May	2	10.3	P. M.	E
	5	4.0	"	E
	8	9.7	A. M.	E

DIONE CONT.

		h		
May	11	3.4	A. M.	E
	13	9.0	P. M.	E
	16	2.7	"	E
	19	8.4	A. M.	E
	22	2.0	"	E
	24	7.7	P. M.	E
	27	1.4	"	E
	30	7.1	A. M.	E

RHEA.

May	4	3.3	P. M.	E
	9	3.6	A. M.	E
	13	4.0	P. M.	E
	18	4.4	A. M.	E
	22	4.8	P. M.	E
	27	5.2	A. M.	E
	31	5.5	P. M.	E

TITAN.

May	2	11.9	P. M.	I
	7	3.0	A. M.	W
	11	5.2	"	S
	14	11.8	P. M.	E
	18	9.4	"	I
	23	12.3	A. M.	W
	27	2.7	"	S
	30	9.3	P. M.	E

HYPERION.

May	3	10.8	P. M.	W
	8	8.3	A. M.	S
	13	1.0	P. M.	E
	19	8.7	"	I
	25	3.4	A. M.	W
	29	12.8	P. M.	S

IAPETUS.

Apr.	27	9.2	A. M.	I
May	17	4.3	"	W
June	6	3.7	"	S

Maxima and Minima of Variable Stars.

MAXIMA

May	2	R Trianguli
	3	S Carini
	3	U Monocerotis
	4	R Lyræ
	6	U Aurigæ
	7	V Ophiuchi
	10	V Virginis
	11	S Virginis
	13	R Tauri
	17	U Geminorum
	18	S Serpentis
	19	T Pegasi
	91	S Vulpeculæ
	20	S Aquilæ
	21	T Herculis
	24	T Cassiopeiæ
	27	R Aurigæ
	29	W Tuari
	31	S Hydræ
	31	S Piscis Austrini

MINIMA

May	1	T Ursæ Maj.
	1	T Libræ
	1	R Scuti
	3	Y Virginis
	10	η Geminorum
	16	S Orionis
	18	S Leonis
	18	R Camelopardi
	21	W Cygni
	22	V Tauri
	22	R Serpentis
	22	R Sagittæ
	29	R Ceti
	30	U Monocerotis

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

May	2	2 A. M.
	4	2 P. M.
	7	2 A. M.
	9	2 P. M.
	12	2 A. M.
	14	2 P. M.
	17	1 A. M.
	19	1 P. M.
	22	1 A. M.
	24	1 P. M.
	27	1 A. M.
	29	1 P. M.

R CANIS MAJORIS.

May	1	3 A. M.
	2	6 "
	3	10 "
	4	1 P. M.
	5	4 "
	6	7 "
	7	11 "
	9	2 A. M.
	10	5 "
	11	8 "
	12	12 M.
	13	3 P. M.
	14	6 "
	15	9 "
	17	1 A. M.
	18	4 "
	19	7 "
	20	10 "
	21	2 P. M.
	22	5 "
	23	8 "
	24	11 "
	26	3 A. M.
	27	6 "
	28	9 "
	29	12 M.
	30	4 P. M.
	31	7 "

S CANCRI.

May	2	11 A. M.
	11	11 P. M.
	21	10 A. M.
	30	10 P. M.

S ANTLIÆ.

(Every third minimum.)

May	1	8 A. M.
	2	7 "
	3	7 "
	4	6 "

S ANTLIÆ CONT.

May	5	5 A. M.
	6	5 "
	7	4 "
	8	3 "
	9	3 "
	10	2 "
	11	1 "
	12	1 "
	12	12 midn.
	13	11 P. M.
	14	11 "
	15	10 "
	16	9 "
	17	9 "
	18	8 "
	19	7 "
	20	7 "
	21	6 "
	22	5 "
	23	5 "
	24	4 "
	25	3 "
	26	3 "
	27	2 "
	28	1 "
	29	1 "
	30	12 M.
	31	11 A. M.

δ LIBRÆ.

May	3	1 A. M.
	5	9 "
	7	5 P. M.
	10	1 A. M.
	12	9 "
	14	5 P. M.
	16	12 midn.
	19	8 A. M.
	21	4 P. M.
	23	12 midn.
	26	8 A. M.
	28	4 P. M.
	30	12 midn.

U CORONÆ.

May	1	6 P. M.
	5	5 A. M.
	8	3 P. M.
	12	2 A. M.
	15	1 P. M.
	18	12 midn.
	22	11 A. M.
	25	10 P. M.
	29	8 A. M.

U OPHIUCHI.

May	1	1 P. M.
	2	9 A. M.

U OPHIUCHI CONT.

May	3	5 A. M.
	4	1 "
	4	9 P. M.
	5	5 "
	6	1 "
	7	9 A. M.
	8	6 "
	9	2 "
	9	10 P. M.
	10	6 "
	11	2 "
	12	10 A. M.
	13	6 "
	14	2 "
	14	11 P. M.
	15	7 "
	16	3 "
	17	11 A. M.
	18	7 "
	19	3 "
	19	11 P. M.
	20	7 "
	21	4 "
	22	12 M.
	23	8 A. M.
	24	4 "
	24	12 midn.
	25	8 P. M.
	26	4 "
	27	12 M.
	28	9 A. M.
	29	5 "
	30	1 "
	30	9 P. M.
	31	5 "

Y CYGNI.

May	1	12 M.
	2	12 midn.
	4	12 M.
	5	12 midn.
	7	12 M.
	8	12 midn.
	10	12 M.
	11	12 midn.
	13	12 M.
	14	12 midn.
	16	12 M.
	17	12 midn.
	19	12 M.
	20	12 midn.
	22	12 M.
	23	12 midn.
	25	12 M.
	26	12 midn.
	28	12 M.
	29	12 midn.
	31	12 M.

New Asteroid 1894 AT, AU, AV, AW, AX, AY and AZ.—These were all discovered photographically. *AX* is the brightest that has been discovered for a long time. At one of the European observatories, however, it was observed visually on the night of March 3, and found to be not brighter than 9.5 or 9.6 magnitude.

		Discovered by	Greenwich M. T.				R. A.			Decl.		Daily Motion.		Mag.
					h	m	h	m	s	°	′	s	′	
1894	*AT*	Charlois	Jan.	29	9	26	8	44	56	+19	24	−48	+2	12
	AU	Charlois	Jan.	29	9	26	8	54	12	+19	56	−48	+3	13
	AV	Courty	Feb.	11	10	45	9	58	24	+22	24	−68	+6	11
	AW	Wilson	Jan.	30	15	22	3	41	25	+24	50	+38	+1	12
	AX	Wolf	Mar.	1	9	05	11	04	36	+ 6	59	−76	0	8
	AY	Wolf	Mar.	1	9	05	11	14	00	+ 4	08	−48	+8	12
	AZ	Courty	Mar.	5	10	14	9	34	24	+23	08	−48	+9	10

New Comet, *a* 1894, discovered by Denning:—A faint comet was discovered by Mr. W. F. Denning at Bristol, England, on the night of March 26. Its position was:

March 26.396 Gr. M. T.; R. A. $9^h\ 55^m\ 00^s$; Decl. $+32°\ 15'$. The daily motion of the comet was 1° south following. The discovery was cabled to Mr. John Ritchie, Jr., of Boston and by him telegraphed to the different observers in the United States on March 28.

The comet was observed at Goodsell Observatory on the night of March 28. It was very small and faint in the five-inch finder but was quite conspicuous and easily observed with the 16-inch telescope. It had a well defined nucleus of the 11th magnitude, and a short tail about 2′ long and spreading to 1½′ width. The nebulosity about the nucleus was quite dense and faded rapidly toward the end of the tail. The position of the nucleus was determined by comparison with an eighth magnitude star north preceding it, resulting as follows:

March 28.6552 Gr. M. T. R. A. 10^h 03 01.58; Decl. $+ 30°\ 58'\ 02''.0$. There are not sufficient data yet at hand for the computation of an orbit.

NEWS AND NOTES.

Experience during the last month makes it very necessary to remind correspondents that proper names should be written very plainly to avoid mistakes in our mailing lists. This is especially true in regard to *foreign* correspondents.

Before his return from Germany, Professor George E. Hale will visit Mt. Etna to make experiments in photographing the corona of the Sun. He plans to reach the mountain about May 15. Mr. Hale's persistent endeavors to discover some way to photograph the corona in full sunlight will, we believe, be rewarded with success before long.

Considerable useful matter intended for the department of Astro-Physics in this number has been unavoidably delayed beyond the time of publication. No one can be rightly blamed for this, for every reasonable effort by those in charge of this department was put forth to supply the matter in time without success.

Lantern Shades at Goodsell Observatory.—Since completing his course of special study, at Goodsell Observatory, Mr. A. G. Silvaslian has given some attention to the making of lantern slides of the photographs of suitable objects made at this Observatory. These consist of views of different phases of the Moon, Pleiades showing curiously intertwining nebulous masses, star trails about the North Pole to show its positions photographically, star clusters, views from the Milky Way, Whirlpool Nebula, minor planet trails, a number of views of the (Rordame?) comet of July last, enlarged views of Sun-spots and faculæ, and numerous other objects suitable for lantern projection, either for class illustration, or for popular lectures on astronomy. Professor William A. Rogers, of Colby University, Waterville, Me., has recently secured a number of these pictures, and he does us the credit to speak very favorably of them.

Professor Turner in the Savilian Chair at Oxford.—A kind note from Professor C. H. McLeod, of McGill University, Montreal, gave us first notice under date of February 9, of the complimentary dinner which was to be given to Professor H. H. Turner February 14, in honor of his appointment to succeed the late Professor Pritchard at Oxford. The dinner was given by the staff of the Royal Observatory, Greenwich, and other astronomical friends, the Royal Astronomer, Mr. Christie, presiding.

The March *Observatory* makes the following note of the occasion: "A congratulatory dinner was given to Professor Turner in celebration of his election to the Savilian Chair, at the First Avenue Hotel, on Wednesday, February 14, by the members of the Observatory staff and several astronomical friends. There were present besides the Observatory staff, Messrs. W. Airy, F. W. Dyson, Dr. A. A. Common, Messrs E. Dunkin, W. Ellis, W. C. Johnson, G. Knott, W. H. Maw, G. C. Pulsford, Dr. Spitta, Messrs S. Waters and W. H. Wesley. Letters and telegrams of congratulation and of regret for inability to attend were read from Capt. Abney, Mr. F. McClean, Mr. W. E. Plummer. Professor McLeod, of Montreal, and Messrs Dickenson and Wilmot of the Commercial Cable company.

Mr. G. E. Lumsden, of Montreal, has in the January number of the *Canadian Magazine* a very readable article on *Common Telescopes and What they will show*. We also notice with pleasure and profit, the articles that John A. Copland has been publishing in the *Globe* of Toronto. They are fully and very neatly *illustrated*.

A Search for Comet of Holmes.—The interest that seems to hover around the comet of Holmes led me to indulge in a thorough search for it during the opposition just past.

During December and January I was observing a star with the Prime Vertical instrument, that came in the early morning hours, and I utilized the time while waiting for the star to transit in making a search for the comet. I used the ephemeris computed from the elements by Professor Boss, as published in the *Astronomical Journal*, until those computed by Mr. Corrigan, and which had been corrected for perturbations, appeared, when I adopted the latter.

Recognizing that the object might appear in the form of an asteroid, each night before commencing the search, I platted all the stars within a radius of 20′ of the comet place. The positions I copied from Argelander's chart, and then compared that with the sky, filling in all the fainter stars that could be seen with our 10-inch refractor. The following night, if clear, or as soon afterwards as possible, I again examined the place to see if any star was missing.

The 10-inch should show stars as faint as the 12th magnitude, and upon each night I have been able to identify all the stars. After platting all the places I swept about two degrees each side of the comet place and although I came upon three faint nebulæ, I was able to identify them in existing catalogues.

If the comet is following its predicted place it is too faint for a 10-inch, and is not as bright as the 12th or 13th magnitude.

There is much in the physical form of comets that awaits our earnest attention. The proximity of comet of Holmes to the Earth at this opposition, in comparison with the distance at which it was when last observed, leads me to believe that we are very deficient in our knowledge of what condition forms what we call the brightness of a cometary mass, and we are compelled to admit that its brightness at a certain distance from the Sun and the Earth is no criterion of what it will be when it again arrives at that point.

In the first of January Professor Brown and I made a search for the comet upon a very clear night with the 26-inch refractor and a nebula of at least the 14th magnitude would not have escaped our attention. GEORGE A. HILL.

Naval Observatory, Washington, D. C. Asst. Astronomer.

Jan. 29, 1894.

Chandler on Observations of Variable Stars at Harvard College Observatory.—In a recent number of the *Astronomische Nachrichten* is a damaging article by S. C. Chandler of Cambridge, Mass., claiming that to some extent at least the observations of variable stars at Harvard College Observatory are not trustworthy. This article will be a surprise to astronomers generally, for the Harvard work has stood very high everywhere. In this guarded paper we are sorry to notice some traces of the former ill-feeling against the director of the Observatory. Doubtless Professor Pickering will have something to say in answer to these charges in due time.

Halley's Comet.—Professor Glasenapp announces that the computing bureau established by the Russian Astronomical Society has undertaken the calculation of the true path of Halley's Comet with a view to predicting the exact date of the next return. He hopes that astronomers acquainted with unpublished observations of the comet will communicate the information to the Society.

Untrodden Ground in Astronomy and Geology.—In the December number of *Science*, page 341, will be found an article under the title: "The glacial period proved as a necessary consequence of the Earth's movements." It was written by J. C. Cowell of England, and is a review of General Drayson's book known by the title: "Untrodden Ground in Astronomy and Geology." We have not seen this book, and know of it only by the article before us. In the opening paragraph of that article Mr. Cowell claims than General Drayson has made a great discovery of a "second rotation of the Earth" (as he calls it) which supplies all the conditions necessary for the explanation of glacial epochs at regular known intervals, in all past or future geologic time.

This is comforting news for the astronomer, for now it seems as if there were some chance for him to agree with the geologist in regard to the data, in time, for past glaciation, in more ways than one. The astronomer has been much interested in late changes of view in regard to the length of past geologic time. Sir Charles Lyell thought the origin of life on the Earth extended back 500,000,000 years; Charles Darwin, in the first edition of his Origin of Species

reckoned 306,662,400 years "as a mere trifle" of that at command for establishing his theory of the origin of species through natural selection. George H. Darwin, professor of mathematics of Cambridge University, England, limits the geologists to 100,000,000, while Professors Tait and Newcomb have named as probable 10,000,000 or 12,000,000 years. Wallace thinks that 28,000,000 years gives time enough for the deposite of geological strata; and now Prestwich and Wright are only asking for 100,000 years as probably time sufficient to include the slow coming on of the glacial period and its rapid close, and that 25,000 years is ample time to allow for the reign of the glacial period. These very marked changes of belief of eminent men of science during the last 40 years are very significant.

But General Drayson gets his conclusions in a much easier way, viz.: by the so-called "Second rotation of the Earth." For the illustrations the copy of *Science* referred to should be consulted. We would not have referred to this article at so great length if we had not received several letters concerning it asking for information on certain points in the article. We reply generally and briefly.

There is no "second rotation of the Earth" in the sense indicated.

The article does not show any proofs of the so-called "second rotation."

The author does not at all seem to comprehend the problems of practical astronomy or the real nature of the data sought by them, or he would not expect to use simple trigonometry to solve them.

In the results given as a proof of his method he begs the question, because he tests his results by those obtained by astronomical methods which he condemns.

Astronomers very well know that the present uncertainty of knowledge of the mean distance of the Sun is such that it would be impossible for them to say certainly just what the eccentricity of the Earth's orbit was at any precise time in the remote past so as to predict for glaciation. The error of the solar parallax alone might make a difference of several times 25,000 years, and the astronomer might be in doubt whether to say polar or tropical conditions or neither reign supreme.

The Chicago Academy of Sciences Section of Mathematics and Astronomy. March 5.—The regular monthly meeting was held at the Chicago Athenæum; Professor G. W. Hough, President, in the Chair. Dr. T. J. J. See read the paper of the evening on "*Gauss' Method of Determining Secular Perturbations, with an Application to the action of Neptune on Uranus.*" The speaker began by pointing out the distinction between periodical and secular perturbations, and then sketched briefly the work of the great mathematicians on the secular inequalities of the planetary motions. After alluding to the work of Lagrange and Laplace, which depends upon analytical developments in series, expanded according to the powers and products of the eccentricities and inclinations of the planes of the orbits, the speaker came to the method of Gauss, which was first developed in a memoir, on the attraction of a certain form of elliptical ring, communicated to the Royal Society of Sciences of Göttlingen in 1818. Since the secular perturbations depend only upon the mean action of the planets from age to age, Gauss conceived the idea of substituting a certain form of elliptical ring for the moving planet; the determination of the attraction of these rings involves the use of elliptic integrals of the first and second kinds.

The mass of the planet is imagined to be distributed around the orbit in such a way that equal areas described by the radius vector will include equal portions of the planet's mass. The author gave the principal step in the investigation for

finding the action of such elliptic rings, and called attention to the high importance of the memoirs of Dr. G. W. Hill and M. Callandreau, which not only develop the theory of Gauss' method, but give auxiliary tables for facilitating its numerical application.

Dr. See then gave the results of his computation on the secular perturbations of Uranus depending upon the action of Neptune, and showed that they agreed very well with Leverriers's values when the latter are corrected for the modern planetary masses. In the discussion of the paper, Professor Hough made some interesting remarks on the history of the discovery of Neptune; Professor Burnham and Dr. Crew also took part. In reply to the question as to the possibility of discovering a trans-Neptunian planet by means of its perturbations, Dr. See stated that if such a planet exists, it will certainly be possible to detect it in the course of time by means of the resulting irregularities in the motions of Neptune and Uranus. Adjourned. T. J. J. SEE, Recorder.

Astronomical and Physical Society of Toronto, Canada.—Meeting of Feb. 19, 1894; Vice president John A. Paterson, M. A., presided.

Professor G. E. Hale of Chicago was elected a corresponding member.

Mr. G. G. Albery of Meaford, Ont., wrote that the Meaford Astronomical Society had been formed.

Dr. Larratt W. Smith sent word of a great meteor which had passed over Nevada and California on Feb. 5.

Mr. G. G. Pursey, librarian, reported receipt of numerous publications. A presentation copy of J. Ellard Gore's new work, "An Astronomical Glossary," was laid on the table, and was pronounced valuable.

A large group of interesting sun-spots was referred to by Messrs. Andrew Elvins, A. F. Miller and G. G. Pursey. A drawing made by Mr. Geo. Willings was handed in.

Papers were read by Messrs. Elvins, J. M. Collins, Chant, Gordon Hull and Thomas Lindsay on "Dynamics," as outlined in Mr. Grant Allen's book on force and energy.

Meeting of Feb. 6; Mr. John A. Paterson, M. A., Vice-president, presided.

Miss Annie Gentle was elected an active member.

Letters were read from Sir Robert Ball, F. R. S., Mr. J. Ellard Gore, F. R. A. S., Professor W. H. Pickering of Arequipa, Peru, Dr. Sanford Fleming, and others.

Professor Pickering was elected a corresponding member.

The society approved of the report that the Sir Adam Wilson telescope be set up at No. 23 Walmer road, the residence of Mr. J. A. Paterson.

Mr. C. P. Sparling laid upon the table the society's fourth annual report. It has 166 pages and contains a portrait of Mr. Andrew Elvins.

The greater part of the meeting was devoted to reporting and discussing observations made upon the Sun, Mercury, Venus, Jupiter, Saturn and a series of auroræ observed mostly on the night of the 23rd of February. The more active observers were:—Messrs. Arthur Harvey, T. Lindsay, A. Elvins, G. G. Pursey, J. R. Collins, S. Hollingworth, R. Dewar, J. A. Copland, W. B. Musson, Dr. J. C. Donaldson of Fergus, John Hollingworth of Beatrice, Muskoka, and G. E. Lumsden.

Mr. Harvey read a memorandum on the size and frequency of sun-spots.

Dr. Donaldson of Fergus referred to a series of difficult double-star observations he has been making, with a view to preparing a list of test-objects for telescopes of apertures of three and one-half inches and less. JOHN A. COPLAND.

PUBLISHER'S NOTICES.

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CONTENTS FOR MARCH, 1894.

General Astronomy: Photographic Nebulosities and Star Clusters Connected with the Milky Way. E. E. Barnard 177
Electrical Clock Connections for Operating the Chronograph. G. W. Hough 184
Meteoric Astronomy. III. Daniel Kirkwood 188
A Small Nebula at M 57. Eugen von Gothard 190
A Photograph of the Pleiades and Two Asteroids. H. C. Wilson 192
Two New Variable Stars. M. Fleming 195
Cometary Shooting Stars. H. A. Newton 196
Long Focus Telescopes. William Rollins 199
Astro-Physics: A Study of Nova Aurigæ and Nova Normæ. William H. Pickering 201
Note on the Spectra of Comets. H. Kayser 204
A Study of Diffraction Gratings—Focal Anomalies. A. Cornu 207
Is there Oxygen in the Atmosphere of the Sun? N. C. Dunér 215
A Short Review of My Theory of the Sun. A. Brester, Jr 218
Astro-Physical Notes 238-245
Current Celestial Phenomena 245-256
News and Notes 256-263
Publisher's Notices 264